

The Virtual *Choga*:
Hybrid 3D Acquisition
of Large-Scale Cultural Heritage Objects
using Mobile Phone Scanning
and PC-Based Photogrammetry

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Abstract

This research investigates the use of digitalisation and virtual reality (VR) technologies in the context of preservation, education, and the experience of cultural heritage sites, choosing the traditional *Choga* house in Jeju Island as a case study.

The project employed a practice-based approach, incorporating spatial characteristics to create a playing path to experience *Choga* in VR. Three types of 3D scanning methods, photogrammetry, videogrammetry, and mobile LiDAR scanning were combined to improve data acquisition for generating 3D model components. The collected data were modified for use within a VR application aimed at creating an experience for users to learn about the cultural heritage.

The results and collected fieldwork experiences reveal the potential of hybrid scanning methods for generating better data acquisition results, but also highlight shortcomings and limitations. Despite the change in focus from creating a serious VR game to improving scanning workflows, this study keeps an eye on the optimisation of content for high-performance game engines to facilitate a positive play experience in a virtual world. Future work could expand the project to an entire village and engage users in a collaborative data collection process for cultural heritage preservation through gamification.

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Abbreviation

DSLR	Digital Single-Lens Reflex
FBX	FilmBox Format
FPS	Frames Per Second
HMD	Head Mounted Display
Hi-Res	High-Resolution
LiDAR	Light Detection And Ranging
LRS	Location, Rotation and Scale
LTS	Long-Term Support
LWRP	Lightweight Render Pipeline
MLS	Mobile LiDAR Scanning
NPC	Non-Playable Character
MR	Mixed Reality
OBJ	Object File Format
SfM	Structure from Motion
SLAM	Simultaneous Localization and Mapping
UDIM	U-DIMension
UPR	Universal Render Pipeline
VR	Virtual Reality
XR	Extended Reality

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Chapter 1. Introduction

1.1 Motivation

I have fond childhood memories of my grandmother's traditional house, which, despite having its interior modernised a little, was always friendly and warm whenever I visited. Stone walls made of basalt, the roof made of straw, and small animals that sometimes came out of them after replacing the roof were a unique experience that this traditional house could give me. In addition, the old-fashioned kitchen and heating facilities, which were in stark contrast to the neatly modernised rooms, were a factor that made me wonder what the whole house originally looked like. As time went by, little by little, my grandmother's house changed its appearance to concrete, slate roofs, and modern interior furniture, leaving only the original exterior wall. Although the modern insulation made the house warmer, in my memory, the wind blowing naturally between the straw roof and the door cover felt cosier. Of course, the modernisation of houses serves to improve the convenience of residents. Still, I wished to preserve the feel of traditional houses that are losing their original appearance or are demolished completely, and convey the experience of it.

With the recent advances in technology in the digital preservation of cultural heritage, virtual reality (VR) is located at the intersection of various technologies as a multidiscipline stakeholder (Liaskos et al., 2022). VR tours can provide various immersive experiences, i.e., visiting the digital reconstruction site of cultural heritage for audiences through stereoscopic head-mounted displays (HMD). Furthermore, with the advent of low-cost VR products, solutions can be provided varying from personal devices to big-scale virtual reality theatres, and this experience can most benefit from the technological layer (Mortara & Catalano, 2018).

This thesis is an attempt to achieve my wish to share my experience of a traditional house named *Choga* through the development of a Virtual Reality tour.

1.2 The Traditional House of Jeju

In studying a specific culture, the traditional house further requires a multifaceted understanding due to diverse factors of formation. Social culture, the lifestyle of natives, superstitions, as well as natural environments affect this formative process (Hanan et al., 2015). *Choga*, the traditional house of Jeju island, was also affected by these multifold factors (C.-H. Lee & Park, 2014). Hyoungjun (2012) also claims that *Choga* has its individual characteristics due to the unique geographical conditions of the island, natural environment,

living culture and folk beliefs. Those factors make *Choga* a different housing style from other houses on the mainland of Korea.

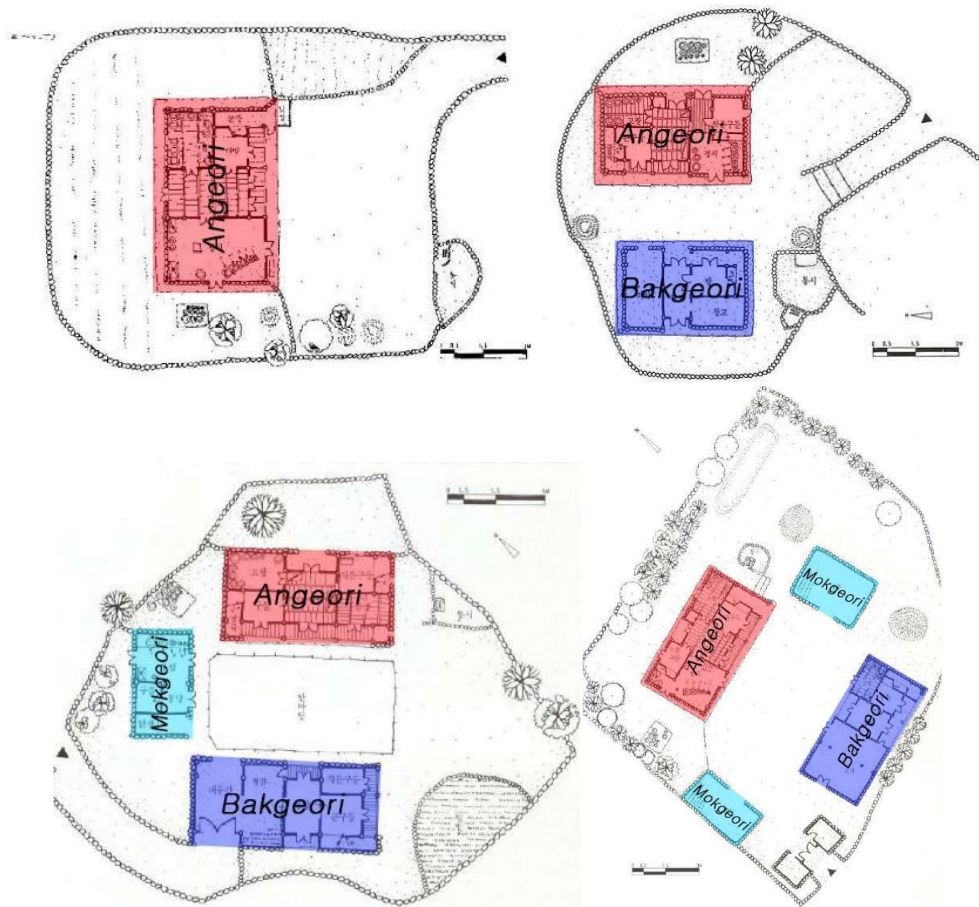


Figure 1. Types and arrangements of *Choga* (adapted from Park, 2016)

First of all, the formation of houses is unique, and the arrangement of buildings (see Figure 1) that make up the *Choga* site is based on various cultural factors such as shamanism, feng shui, climate, and the unique family system that exists only in Jeju Island. In Korea's traditional housing culture, the inner house is usually used as a women's space, the outer house is used as a men's space, and the residential space is separated by gender. On the other hand, Jeju Island has a unique housing style in which the generation of children lives in the inner house (*Angeori*, the red house in Figure 1), and parents live in the outer house (*Bakgeori*, the blue house in Figure 1), separating the residential space by generation.

Besides, the construction method of the building has changed due to the strong prevailing winds on Jeju Island. Houses were built with a low height and a wide sideways structure (see Figure 2), extra doors were attached to windows or walls to block the wind, and wind covers called *Pungche* were attached to the roof railings (C.-H. Lee & Park, 2014).



Figure 2. Outer appearance of *Choga*

In addition, shamanistic beliefs influenced *Choga* from the architectural design process. The shamanistic belief of possession of a place or object by gods is a common culture in Korea. Especially myths around household gods are most widespread, and even in modern times, they are still used with various attempts of reinterpretations, even using multimedia (M. Lee, 2015). In particular, Jeju residents believed and awed them with the traditional charm that household gods lived in each section of the house, and the belief can be confirmed through local oral traditions. The story of the household god has been passed on orally as the song *Seongjupuri*. This song is performed for the ritual ceremony *Seongjugut* upon moving into a new home (Korea, 2015). Also, there is a ritual period for repairing or moving into a house called *Shingugan*. During this period, starting five days after the coldest day in the year (Dae-Han) and ending three days before the start of spring (Ip-Chun), the previous god has left to the heaven of gods to transfer ownership to a new god, and the house is “unoccupied” (Jeju Special Self-Governing Province, n.d.). Even though this specific moving term still exists with a different name as a visitor-less day in other areas of Korea, only Jeju island has this detailed background story. With the combination of *Shingugan* and *Seongjugut*, the household god is more familiarly incorporated into the life of the villagers of Jeju.

There is also a unique myth of household gods that originated in Jeju island. The song of the origin of the seven stars (*Chilsungbonpuri*) is the story of the birth and the deification of seven stars (*Chilsung*), a snake god that oversees the fortunes of a family (Korea, 2015). The legend of gate god *Munjeonbonpuri* is another story of a household god for specific areas in *Choga*, e.g., the kitchen, the main gate, and the toilet. The song is based on the family's journey of being gods, mythical talks that people should live wisely and guard against foolishness. Additionally, this tale includes a warning to avoid doing evil by showing the punishment that the toilet god received (National Folk Museum of Korea, n.d.).

Unfortunately, among the traditional thatched houses in Jeju, only a few houses in Seongeup Folk Village were preserved, and most of them were demolished (Hyunjoo Han & Sang Hoon Lim, 2020) or modernised (C.-H. Lee & Park, 2014). Therefore, this thesis focuses on the specific *Gaekjijip* House (National Folklore Cultural Heritage #68, Korea) among the preserved houses in Seongeup Folk Village (see Figure 3).



Figure 3. Maps of the location of Jeju Island and Seongeup Folk Village (adapted from *The National Geographic Information Institute of the Republic of Korea*, n.d.)

In the upcoming chapter, I will delve into the literature review surrounding my study's topics, which include the digital preservation of cultural heritage, its context in museums, virtual reality preservation, a serious gaming case study, and 3D data acquisition. Chapter 3 will provide insight into the design process, including the shift in thesis focus from developing a serious game with digital heritage to exploring hybrid 3D acquisition techniques for cultural heritage after a "series of unfortunate events" brought about by the COVID-19 lockdown. Chapter 4 will detail the preparation and actual scanning process during two data acquisition trips to the *Choga* site. Finally, in Chapters 5 and 6, I will discuss the outcomes of my 3D scanning exploration, its limitations and expectations for future research, and conclude my work.

Chapter 2. Literature Review

2.1 Digital Preservation...

In November 1972, at the Convention on the World Culture and Natural Heritage, the United Nations Educational, Scientific and Cultural Organization (UNESCO) first proposed the concept of cultural heritage and presented the need for global protection of various intangible and tangible cultural properties in each country (United Nations Educational, Scientific, and Cultural Organization (UNESCO), 1972). Various efforts to preserve cultural heritage have been made so far, and physical protection and preservation have been mainstream, but thanks to the development of virtual technology, digital preservation is also being explored. Zhou et al. (2012) defined the digitalisation of cultural heritage as the process of digitalising the movable or unmovable cultural heritage using contemporary remote-sensing and virtual technologies to achieve 2D or 3D digital archiving. In digitisation, for tangible cultural heritage, data are generated to be recreated and preserved target in detail not only in its overall form (Coenen et al., 2013) but also in reflecting the characteristics of their surfaces (Levoy et al., 2000), unique components like a wall painting (Soto-Martin et al., 2020) and the extent of their damage. Furthermore, data are also used to restore the past based on the remaining unbroken parts (Cawthorne & Irodoutou, 2016). In addition, based on the architectural style analysed from the digitised data (Hanan et al., 2015), it is used as a clue to predict the sites of the past city reflecting the culture (Fadeeva et al., 2021) or to recreate cultural heritages lost by a natural disaster, e.g., sinking to the sea floor due to climate change (Bruno et al., 2018). The data acquisition of cultural heritage is generally achieved by optical technologies such as photogrammetry, laser scanning (Potabatti, 2019) or generating point cloud data by SfM (Structure from Motion) technologies (Spreafico et al., 2021). In the historical aspect, Potabatti (2019) noted that the concept of photogrammetry was started in the 1400s by renaissance painters to involve geometrical analysis in their work. In recent times, through the exponential growth of cameras, optical recorders and computational devices, this technology has been used in various industries in archaeological documentation, industrial inspection and medical data acquisition.

The integration process for the digitalisation of cultural heritage has to be flexible due to the diversity of scale of the target heritage. From small monuments to urban areas or huge natural objects, the object of digital preservation is not only considered on a scale accessible to real life. In addition to the data collected through the preceding process, if the destroyed or lost part of the collection target needs to be supplemented, additional data may need to be recreated based on the collected data and augmented for scanned data. Pietroni and

Ferdani (2021) introduce the restoration through the combination of these hybrid data as virtual restoration. The components of cultural heritage can be the clue of this digital supplement. In digital restoration, Cawthorne and Irodotou (2016) restored a Cathedral, St. George of the Greeks in Cyprus, with the destroyed roof and lost parts of the external walls restored based on analysing data of the digital preservation model of it. Based on the traces of the internal structure and the architectural style at the time, they were able to symmetrise the remaining structures and the 3D mesh data through space measurements to digitise some of the cultural heritage that is not currently remaining. The texturing process needs to focus on precise colour data to improve the visual aspect of 3D models and may hold important information to be preserved. Dhanda et al. (2019) describe the workflow of recreating the real environment of cultural heritage *Myin-pya-gu*, the ancient temple in Myanmar, by SfM photogrammetry (see Figure 4). The result of this research project shows the data collection of the high-resolution surface texture is suitable for reconstructing cultural heritage within various content platforms (Dhanda et al., 2019).

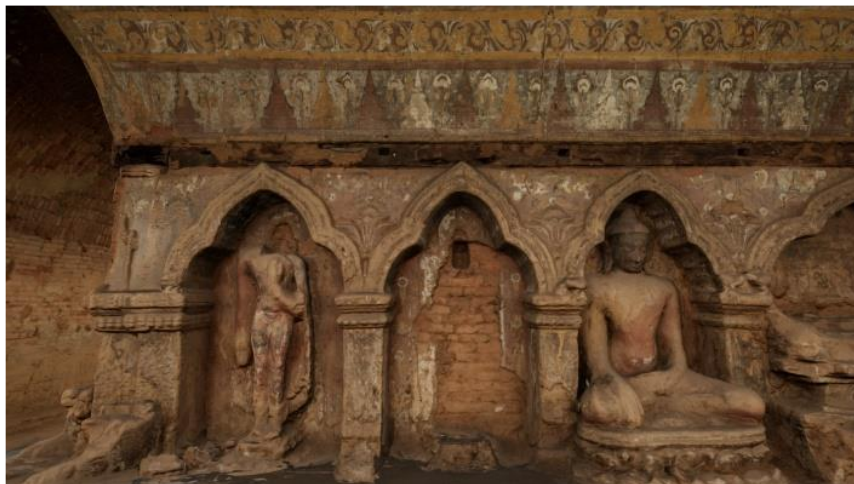


Figure 4. Photogrammetry capture of *Myin-pya-gu* (adapted from Dhanda et al., 2019)

The study by Hanan et al. (2015) shows the reconstruction process of *Batak Toba* traditional house as a 3D model to preserve its cultural value as the collective memory of the original community. The team used close-range photogrammetry to scan the house's external structure and distinguish scanned building components to cover each surface with detailed texture (Hanan et al., 2015).

2.2 ...In the Context of the Museum...

Along with the development of the digital preservation of cultural heritage, digital archiving through the application of digitalisation technology can be useful in many places, especially in museums. In particular, systematically organised archive data can be provided to users in

the form of virtual visits in addition to physical museum visits. This virtual museum is one of the achievements of the preservation of historical heritage in digitalisation. Zhou et al. (2012) state that this digital museum breaks through many bottleneck issues of traditional museums through the potential of its unique characteristics, such as storage digitisation, networking capabilities, and resource sharing. Besides, the digital museum can amplify the audience's immersion with a multi-dimensional experience through a mixture of advanced technologies: Computer graphics, Emulation technology, Multimedia technology, Computer networking technology, Artificial Intelligence, and multi-sensor input/output to address the user's senses such as through haptic feedback. Furthermore, in the virtual museum, it is possible to augment information about the contents of an actual museum with various multimedia methods, such as a combination of two-dimensional images and text and a three-dimensional model. In addition, Döker and Kirlangiçoğlu (2018) claim that this digital platform has many more advantages than visiting the real cultural heritage space due to its high accessibility and ease of use. Users can access the virtual museum with just computer devices and an internet connection. This platform allows them to see all of the components of cultural heritage and information interactively with only mouse clicks.

2.3 ...In Virtual Reality...

Fadeeva et al. (2021) argued that virtual reality (VR) is a way to preserve cultural heritage and attract the attention of a large audience. In the aspect of digitalisation technology as a virtual environment reconstruction, studies suggest that VR has the potential to provide immersion by a holistic experience with spatial components such as sound, cultural elements, and the folkloristic or religious occasion of the target space. Furthermore, regarding the educational perspective, VR can also effectively motivate users to learn about existing architectural locations, encouraging them to engage in real experiences (Mortara & Catalano, 2018). Debailleux et al. (2018) created a virtual tour of the city of Mons in Belgium. This tourism application is designed to introduce the buildings of Mons through a voice description for children aged 9 to 12. The authors claim that the virtual tour has possible benefits to improve the achievement of spatial cognition and learning of the target cultural heritage (Debailleux et al., 2018).

However, there is also concern that users often lose interest in the target cultural heritage because they are overwhelmed by the virtual environment experience (Hoang & Cox, 2018). Various solutions are cited to improve users' attention to heritage. Under the physical aspect, a physical replica of virtual heritage is installed to provide real interaction, and it also

makes the user's experience synchronised between VR and physical augmented space (Hoang & Cox, 2018).

2.4 ...With a Serious Game Approach

The presentation of cultural heritage through serious games in virtual worlds has gained popularity as a means of preserving and educating about cultural heritage. Two notable studies in this field are “Learning Cultural Heritage by Serious Games” by Mortara et al. (2014) and the Museum of King John III's Palace by Choromański et al. (2019). Mortara et al. (2014) noted the advantage of reforming virtual heritage into a serious game. Through the proposition of a serious game for the cultural sector, the authors claimed that it could improve the audience's cultural awareness and increase their interest in historical reconstruction and heritage awareness.

Specifically, Choromański et al. (2019) reconstructed the King John III's Palace Museum to provide visitors with a virtual space. The team tried to compare various methods of 3D scanning data of objects of the palace, such as decorations, sculptures on the wall and gothic furniture. From the comparison of the texture data set of modellings, the researchers were able to show the different results of data set optimisation up to its scanning quality for gaming content.

In both projects, the authors investigated the use of serious games in teaching cultural heritage and concluded that these games effectively enhance players' knowledge and understanding of cultural heritage sites.

Another relevant example of the use of serious games is the interactive VR documentary “Home After War,” which is available on the Meta store (Gayatri et al., n.d.). “Home After War” shows the situation and reality of war in Iraq by providing a scanned model of a damaged house with the narration of the householder. This interactive content focuses on rebuilding a community after a war and reconstructing a real living space and home. Players face two moments when the destroyed house is rebuilt and can compare both in a timeline by hologram guide.

2.5 3D Acquisition

With respect to the technology used for digital preservation, photogrammetry is frequently utilised. In the technical demonstration of Gomes et al. (2014), researchers subdivide the photogrammetry workflow for cultural heritage into four stages: data acquisition, registration,

integration and texturing. According to their classification, in the data acquisition stage, choosing the correct methodology, tools, and cost needs to be considered depending on the object's nature and the purpose of its digitisation. In the registration stage, finding an optimised alignment between the collected data is important to improve the accuracy of the result. For high accuracy, various approaches, such as hybrid methodologies and the combination of various tools, are being used. Many attempts have been made to combine additional geometric information to increase the reliability of location information during the alignment of collected optical data. Markovic (2018) demonstrated how to achieve a more accurate 3D model of cultural heritage in her project using point cloud data obtained from LiDAR scanners. Furthermore, she included additional steps to create high-resolution textures from pictures, matching each point of the surface colour and surface structure. Bennet (2021) introduced a cultural heritage reconstruction project of Hillary's Antarctic Hut through photorealistic virtual reality. Bennett involved Markovic's data acquisition process in the project and combined it with interaction development in a game engine. From Luetzenburg et al.'s (2021) evaluation of co-registration between photogrammetry and mobile LiDAR scanning with an iPhone 12 pro, the 3D model data generated in the registration test for a large coastal cliff face (length: 130m, width: 15m, height: 10m), also demonstrated high accuracy, and that convergence cases using mobile LiDAR applications could be utilised as well as high-cost LiDAR scanning processes used in specialised industries.

Chapter 3. Design

3.1 Research Question

"Can mobile phone-based LiDAR and videogrammetry scanning technology be used to supplement traditional photogrammetry scanning technology? Moreover, can it serve as an alternative in certain environments?"

These questions served as the basis for this project. They were raised to improve the second data acquisition process, following problems that I experienced during the first 3D data acquisition process attempt targeting the large-scale cultural heritage object *Choga*.

The original question of this thesis, "Can characters related to the culture enhance immersion in cultural heritage reproduced in virtual reality?", was abandoned due to major issues faced during the course of this research (more about that in the next section).

However, the macroscopic aspects of the first data acquisition process such as fieldwork and data processing methods were maintained while reducing the story and gamification process that became unrelated to the final question.

3.2 Methodology

Because the setting of this project is the exploration of the usability of a hybrid scanning method and comparison with the traditional way of 3D acquisition, this project is approached via practice-based research. According to Candy (2006), practice-based research is defined as gaining new knowledge based on the research practice or the legacy of that practice. Candy claims the eligibility of the practice-based research method for design, models and multimedia content. Furthermore, he highlights the necessity of a wide range of professionalism in various industries to utilise practice-based due to the difficulty of evaluating this research's method. Therefore, the reason why I adjusted the project process between 2019 and 2022 was to gain new knowledge by not only using a "research lens", but also incorporating insights from both processes. Besides, from the knowledge gained during the 2019's data acquisition, I refined the 2022's process by revising each stage during the implementation. To accomplish my research design goals, I sought to apply the agile development process (*Manifesto for Agile Software Development*, n.d.) to my 2022 data collection plan. This development methodology diverges from traditional approaches that rely heavily on static preliminary plans, instead embracing adaptability throughout the project's various phases. This methodology, informed by prior experiences, is anticipated to

enhance and streamline the data collection process. This proactive stance is intended to ameliorate issues stemming from incomplete data collection, a challenge frequently arising from the influence of dynamic environmental and contextual variables during the data acquisition phase.

3.3 Overall Workflow

This research aims to combine photogrammetry and mobile LiDAR scanning to improve cultural heritage reconstruction and compensate each scanning method's weaknesses. To compare the efficacy of the different scanning techniques, I separately used all methods to scan the *Choga* dwelling site, a distinctive architecture indigenous to Jeju island, to determine the respective data acquisition method capabilities in reproducing *Choga*. The study culminated in combining the outputs from each technique to create a comprehensive digital heritage representation.

The project's original focus (referred to as “2019 version”) was more on the gamification aspects, but it was changed to concentrate more on the technological side of the acquisition process (referred to as the “2022 version”). The original idea aimed to reproduce cultural space and integrate the spatial experience and related story with characters originating from traditional myth. For the aim above, the first project has been run into two major stages: pre-production and production. Figure 5 indicates the overall workflow and pipeline that this project used in 2019. In pre-production, the main focus of the legend aspect is a design of housing gods as Non-Playable-Characters (NPC). This step has a strong influence on the planning that limits the playing path on the heritage side.

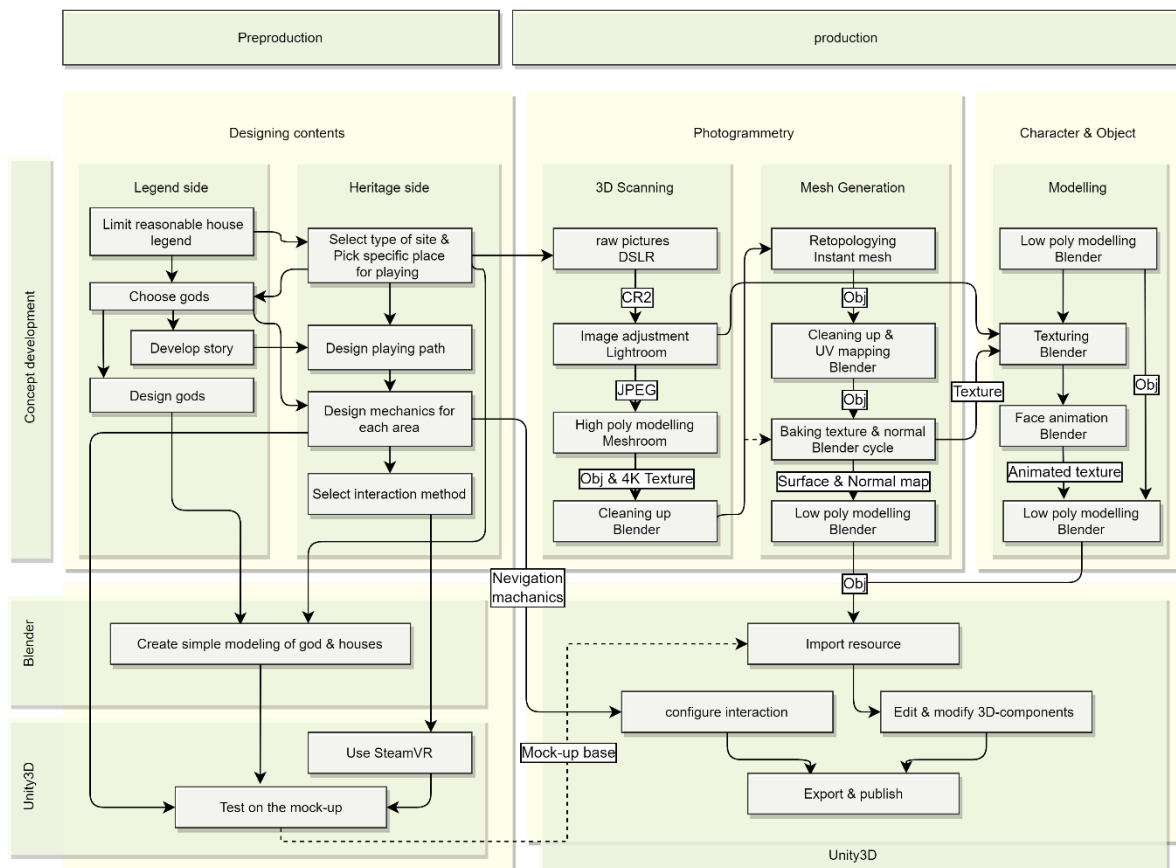


Figure 5. Overall workflow design (2019 version)

However, during the course of the project in this version, while data acquisition for the target cultural heritage and the creation of 3D models for each character and user interaction within VR were completed after pre-production, the level design process within virtual reality was halted due to the inability to access the targets that required re-scanning caused by the onset of the COVID-19 pandemic, and the research was eventually discontinued due to my deteriorating health caused by the prolonged lockdown.

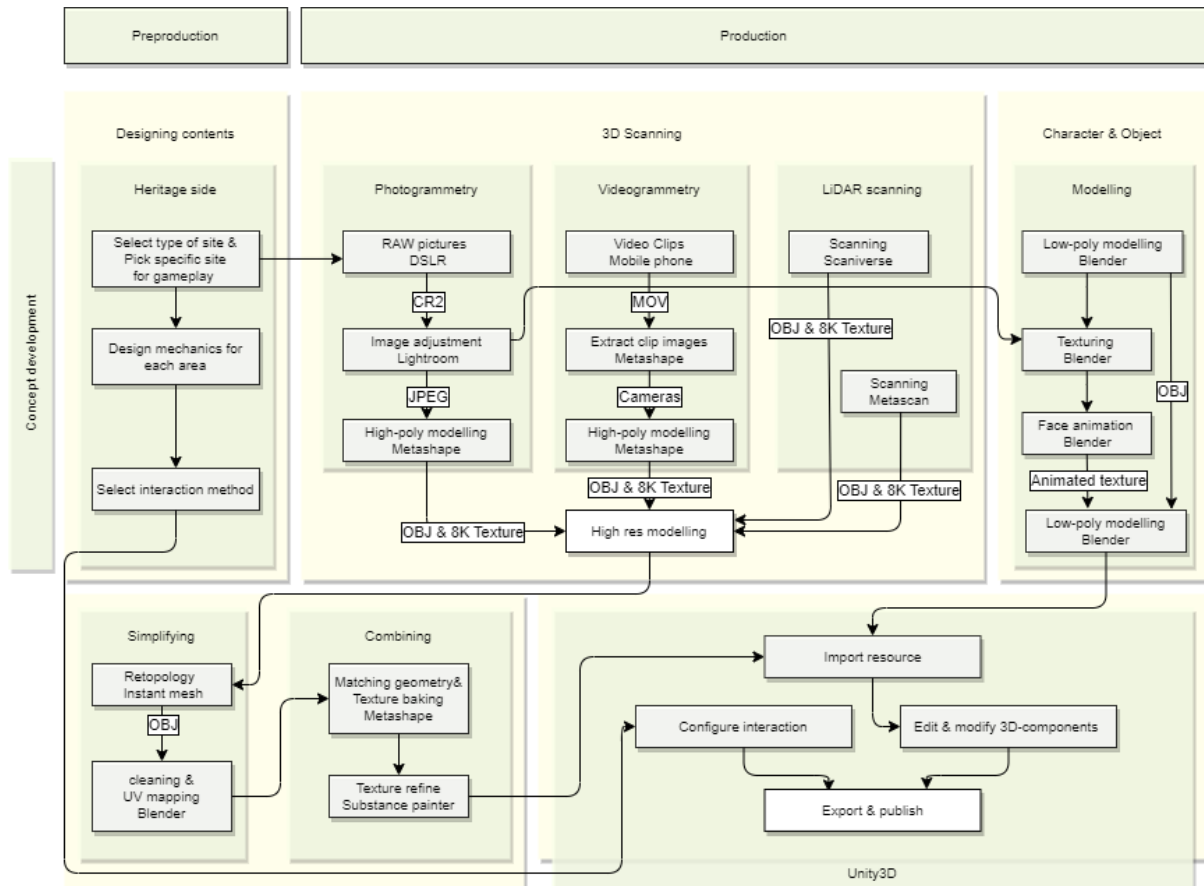


Figure 6. Overall workflow design (2022 version)

The flowchart in Figure 6 illustrates the redesigned workflow for resuming my study in 2022. During the production stage of this workflow, due to new mobile technology available, 3D scanning became a central mission for the project. Consequently, the narrative design from the previous plan was scaled down, leaving only characters to introduce each cultural heritage location as non-movable NPCs. Furthermore, the scope of interaction design was limited, focusing merely on locomotion through the *Choga* site. To provide more details on the 3D scanning plan, I divided the 3D scanning process into three types: photogrammetry, videogrammetry and LiDAR Scanning. By comparing and integrating the results from each method, I was able to create comprehensive scanning data. The selection and determination of equipment and programs for 3D data collection were adjusted based on the results of previous projects and left as a subtask. Additionally, as the proportion of 3D scanning increased, the post-processing steps for the integrated data, such as the simplifying stage of the 3D model and its integration process, were elevated to major steps. The main workflow changes between 2019 and 2022 can be seen in Figure 7.

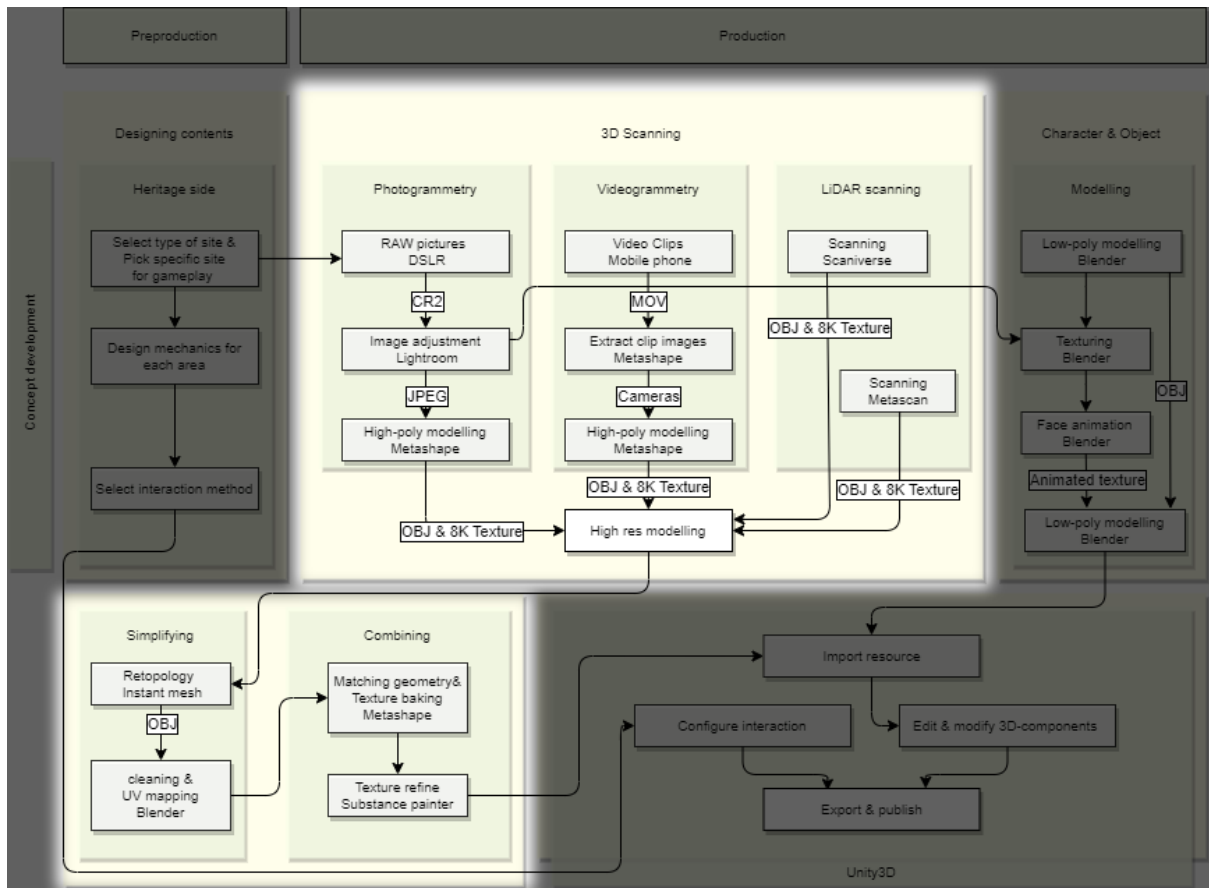


Figure 7. Main changes in the workflow from 2019 to 2022

As discussed above, the primary modification of the new workflow pertained to the production stage's 3D scanning and data acquisition phase. This updated approach employs three different scanning techniques: photogrammetry using images from the 2019 workflow, videogrammetry using footage captured on a mobile phone, and LiDAR scanning performed on the same phone used for video recording. Once the data acquisition is complete, the scanning data is exported in a uniform format consisting of OBJ files and 7,680 x 4,320 pixels resolution (8K) textures, ensuring the preservation of texture quality from the original sources.

3.4 Content Design

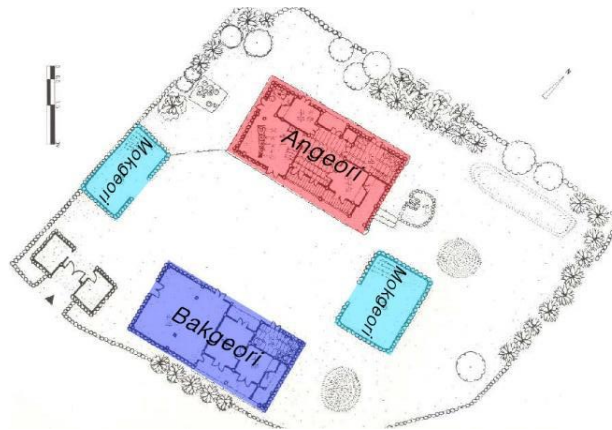


Figure 8. The specific arrangement of *Choga* in this thesis (adapted from Park, 2016)

Choga can be categorised into four types according to its components on the house site (C.-H. Lee & Park, 2014). The purpose of this project is to implement in virtual reality the specific formation seen in Figure 8, which includes two horse stables, a multi-purpose warehouse, the inner *Choga* where the head of the household resides, and the outer *Choga* where the parents live. This formation corresponds to the *Gaekjujip* House, which is located in Seongeup folk village and designated as a national folklore cultural heritage site by the Korean government. Therefore, I needed to obtain permission by contacting the folk village in advance to access the cultural heritage site and collect data for research purposes.

As described in section 3.4, the content design related to narrative and gamification was reduced or not utilised in the second stage, which resumed in 2022 after the first stage in 2019. In this section, I will briefly introduce the main story elements that served as the foundation at the beginning of the project and discuss the planned level design as a game element. Additionally, I will describe the characterization process of household gods remaining in the content, along with supplementary explanations.

3.4.1 Background Story Design

The main story involves the user moving into a new house on Jeju Island, where they encounter gods residing in the house. These gods challenge the user to prove their ownership rights. Additionally, a ritual is required to summon a new god to protect the house from evil invaders due to the current house god's insufficient power. To advance in the story, the user must gather resources for the ritual by completing missions assigned by each god.

Based on this story, the following gameplay objectives can be defined as the primary mission and secondary missions:

Primary mission: Prove ownership of the house to the house gods. Perform a spiritual ceremony with other gods to bring a new god to the house (collecting ingredients).

Secondary missions: Protect various locations (the entire living area, such as storage, outer yard). Obtain food ingredients (which can also be ritual resources) from storage or the yard.

Additional information about the cultural heritage in Jeju as well as the original myths and cultural tales that form the background knowledge for the story and missions above are located in Appendix 1.

3.4.2 Play Path Design

The initial direction of the project included research on the gamification of digital cultural heritage, which also involved studies on designing user play paths. Although this was not fully implemented in the final version, the narrative is still part of the long-term vision and future work, and therefore presented here for the sake of completeness.

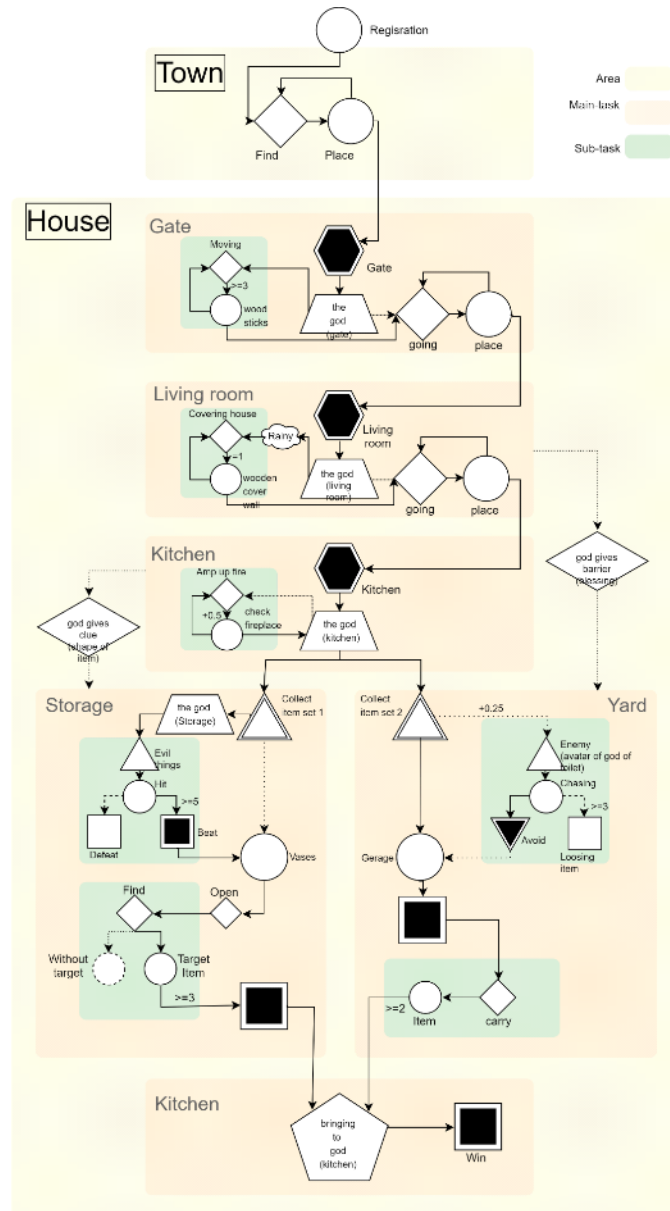


Figure 9. Play path structure

The pre-designed play path aimed to guide users from the village square to the site of *Choga* and from the site's entrance to more specific locations within each house (see Figure 9). This path leads the user through key locations to introduce the functionality of each part of *Choga* and the features of various architectural components. Although the play path appears to be linked to each main task in Figure 9, it was designed to be flexible, allowing for movement anywhere during the journey as a modular structure. Furthermore, every main mission includes a sub-task in the form of a mini-game based on a related myth, which aims to enhance immersion and increase interest in *Choga*. A detailed explanation of the mechanics of the play path can be found in Appendix 1.

3.4.3 House God Design

Similar to the play path, the importance of the house gods was reduced in the second stage. However, I will present some design considerations here again for the sake of completeness. A detailed summary of their personality and characteristics can be found in Appendix 2.

The household gods were designed as characterisations appearing as mascots. Although numerous house gods exist in every area of *Choga*, it was necessary to choose the main gods to optimise the journey. Therefore, among the household gods from *Sungjupuri*, *Chilsungbonpuri* and *Munjeonbonpuri*, six gods are selected according to matching their occupying place with the quest field.

In the early phase of character design, studying the silhouette of the character makes it clear and more accessible to validate the readability of characters and their personality (Ekström, 2013). Also, users may feel different familiarity or discomfort with the character depending on the character's overall shape. Furthermore, this feeling is further maximised by adding the represented colour of the character's personality.

In the original legends of the household gods, the gods used to take on the shape of human figures. However, I decided to redesign the house god NPCs to bear a simple shape so that even users unfamiliar with the background culture and myth can more easily accept them. To be specific, the design aims to induce a friendly feeling because most of the gods will partner with the user as guides during the journey. A circular shape is suitable for this aspect because its characters are recognised as the most friendly as they have no harmful or spiky features (Solarski, 2012).

The notion of ascribing amiable sentiments exclusively to deities is insufficient for endowing them with distinct personalities. Furthermore, a mere geometric representation, such as a circular figure, is inadequate for expressing the individual character of each deity. Specific attributes related to their appearance are essential to convey their unique essence. In order to capture these features, I have compiled a list of characteristics for each household god, focusing on a select number of factors. These properties, which facilitate the organization of the gods' attributes, can be found in Appendix 2. The factors encompass each deity's personality, origin story, and relationship with other gods.

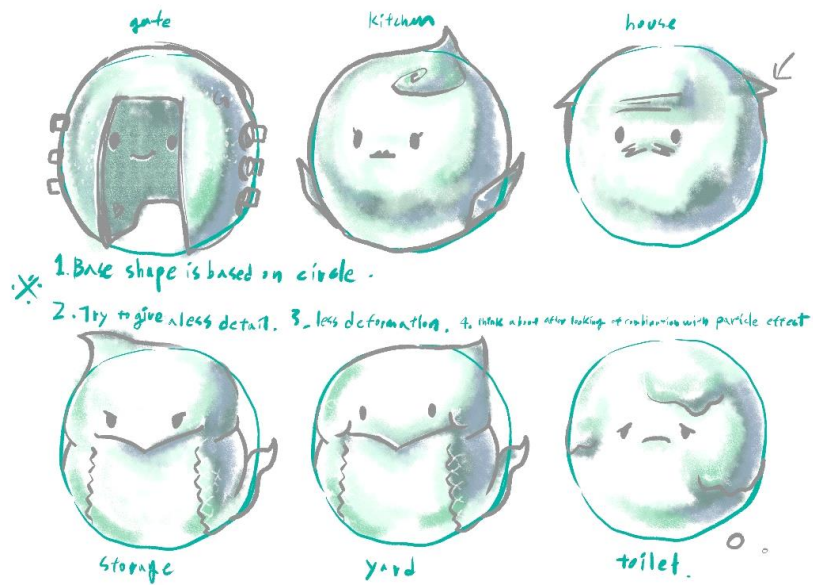


Figure 10. Prototype concept design for the household gods

The design of the household gods was determined through multi-dimensional considerations of their origin, location, and characteristics. Figure 10 presents prototype sketches of each of the six chosen deities created with these considerations.

The first character resembles a traditional gate in *Choga*, indicating the god's position. The second god, who controls fire in houses and resides in the kitchen, is represented by a flaming shape. The third character's shape serves as a metaphor for a house, as this god leads the household gods and detects and protects the site from unholy existence. The fourth and fifth gods reside in the storage on the house site. The geometry of the island's isolation from land led people in Jeju culture to revere snakes as protectors of meals and wealth from mice in storage. Accordingly, the God of storage in the Jeju myth is represented in snake form. Finally, the last character in Figure 10 symbolises the god of the toilet. In the Jeju myth, this deity was punished for her crimes.



Figure 11. Representative charms of household gods

The concepts of deities' appearances were adjusted based on the ritual equipment of Jeju's cultural ceremonies, following the Jeju myth's reconfirmation. Figure 11 depicts paper charms that symbolise household gods in the "Choga" site. The first and second charms represent *Sung-Ju-Shin*, the house god, with their folding shapes representing the house's roof. As mentioned earlier, the last charm signifies the god of storage in a simplified snake form. Following these paper charm shapes, the appearance of specific deities was redesigned, incorporating the concept of charms.

When the gods first come into contact with the player, colour is one of the powerful components to represent their characteristic (Sloan, 2015). Colour selection is quite important to introduce each god to the user without a detailed explanation. However, cultural diversity of the user can affect how the meaning of colour is interpreted.



Figure 12. Selected concept and colour design for the household gods

Figure 12 represents the household gods, which were embodied by incorporating the shapes of the actual ritual tools referenced in Figure 11, along with the temporary form established in Figure 10. The colour of each deity was assigned to reflect their abilities, roles, and positions. The two gods on top, *Seong-Ju-Shin* and *Mun-Shin*, were assigned the colour

blue, which symbolises solidity and faith in various cultural contexts, as they are responsible for protecting the location they inhabit. However, *Mun-Shin*'s design incorporates the material of Jeju Island's main topographic element, basalt, in virtual reality. The third deity, *Jo-Wang-Shin*, who manages the fire within the household and is depicted as a woman in the myth of the origin of the hearth, was assigned the colours red and orange, which represent fire, along with facial features that resemble those of a woman. Fourth, *An-Chil-Sung* is composed of a single deity, unlike Figure 10, as an attempt to increase indoor encounters with the gods. This god is associated with wealth and is represented by yellow or gold. The fifth deity, *Chuck-Shin*, resides in the toilet and is depicted with negative colours, such as greenish-brown and a fierce expression, as it has been subject to punishment. Finally, *Mun-Jeon-Shin*, who oversees the household gods and protects the house from evil, was designed with a magnifying glass shape and coloured purple to symbolise wisdom and loyalty.

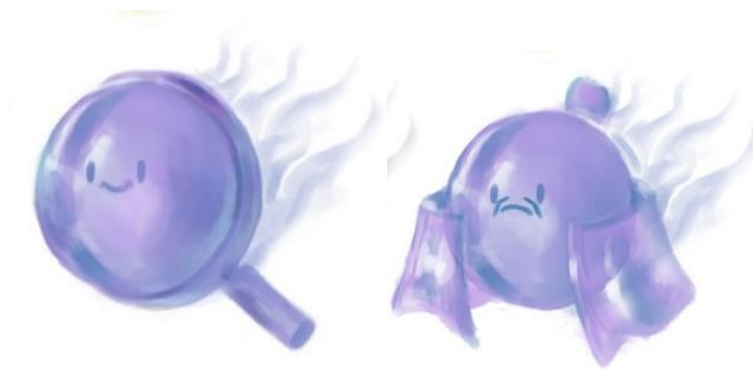


Figure 13. Changed design for the overseer of the household gods

During the creation of the appearance of the household gods embodied in Figure 12, I received feedback that the magnifying glass shape representing *Mun-jeon-Shin* was challenging to connect with and had ambiguous symbolism. *Mun-Jeon-Shin*'s design was revised to include traditional Korean hairstyles, the addition of a beard to convey a more mature appearance, and a cloak to highlight the role of *Mun-Jeon-Shin* as the overseer of the household gods. Figure 13 shows the changing appearance of god according to this consideration.



Figure 14. Finalised household god models in VR

Figure 14 represents the appearance of each deity placed within the virtual reality content. The top six designs were adjusted during the development stage in 2022. The four characters below were temporary designs created for testing purposes during the development process in 2019.

Chapter 4. Development

Before digging deeper into the project's development phase, it was essential to establish a standard for selecting programs or tools. Given the limited development resources, the primary considerations for selection were low cost, minimal mobilization of staffing, and availability of support resources such as detailed manuals, various case studies, or low-level manipulation. Additionally, due to the complexity of the data acquisition process, adequate preparation was necessary to enable testing across various scenarios. With this in mind, this chapter will delve into the digital preservation journey of *Choga*, including two data acquisition trips and the finalising process in VR space, focusing on the aspects mentioned above.

4.1 Development Environment

Before building the mockup, selecting a specific game engine as the development environment (e.g., Unity or Unreal engine) was necessary. I chose Unity simply because of my previous experience with the engine.

Next, I had to choose the input system exclusive for VR or MR, e.g. Steam VR or the VR interaction toolkit by Unity. These input systems provide features to create interactions in VR such as moving, touching or holding objects in the virtual world. In the primary development, the input system chosen was SteamVR due to its stability. Also, the first development VR gear was an HTC Vive Pro, so control mappings were adjusted for the Vive controllers.

In this stage, another aim was to study which locomotion method is suitable for exploration and play in a virtual space journey. Various methods have already been analysed in various projects. LaViola et al. (2017) describe three types of travel methods in virtual space. Firstly, change position by selecting the target or direction, the example of this method is usually observed in games, such as moving by clicking the object in sight, touching a “milestone” when going to the next destination, or teleportation to another country by choosing flag on a globe.

Second, selecting velocity or acceleration is adjusted by a constant input, changing of user's gesture, environment scaling or automatic/ adaptive mechanics during the travel.

Third is input from any of the VR controllers. It includes changing the state of moving according to any input. Initially, I decided for two methods: using a button to move in the direction of the HMD, and teleportation by picking a specific area in a “holographic” minimap on the left wrist of the user's hand in VR.

In the second phase of this thesis, the development changed in several aspects: changing VR gear from HTC Vive Pro to Meta Quest 2, resulting in the need for low computing specifications, changes of the photogrammetry software from Meshroom to Metashape and a mobile LiDAR application, and capturing hardware changing from a DSLR camera to a mobile camera. However, the project target, *Gaekjujip*, was maintained, so the 3D mockup model remained as a basis for integrating new 3D scanning data.

4.2 Site Mockup



Figure 15. Mockup model of *Choga* for play-testing

Due to the original design focus on a play-based simulation, the first step of development was a building mockup of the site of a house from a site plan such as Figure 8 itself.

To build a mockup model, *Blender*, the freeware 3D modelling application, was chosen not only for low polygon modelling but also for future edits of 3D scanning results. Even though both processes require different modelling abilities for the 3D tools, *Blender's* expandability with user-made add-ons was considered a selection factor. To be specific, it is necessary to optimise the polygon count of scanned 3D models and the quality of texture for good performance on the game engine. Therefore, after the mockup process, *Blender* was still

used for modifying and cleaning the result of 3D scanning objects in this project for the above purpose.

For the mockup, house and site models were first made in simple shapes to test the VR locomotion method, achieve accurate height for the user's perception, estimate necessary texture resolution, and test the play path plan.

4.3 First Acquisition Phase





4.3.1 Planning

Prior to actual 3D capturing the target heritage object, It was necessary to test and select applications and capture equipment to reduce complications in the field as much as possible. In addition, since it would be challenging to re-photograph the target, the shooting locations were chosen in advance as much as possible through the site information available online.

4.3.1.1 Selection of Photogrammetry Application

The photogrammetry application is a vital item to reconstructing the content for this project. There are numerous existing applications for 3D capture, so the following comparison (Table 1) lists the pros and cons of each of the four applications chosen as candidates for reproducing *Gaekjujip* in the virtual world.

Due to the possibility of an extension of the schedule for data acquisition, the first factor for selection was how readily available each of the four applications were for the time. For this, I checked each application's cost and current availability for the university. *Meshroom* and *ReCap* have the advantage that they are free to use for educational purposes. Even though *Reality Capture* was also available through the faculty, I could not rely on it long-term because it does not support a floating license.

Application	 <i>Reality Capture</i>	 <i>Meshroom</i>	 <i>Recap Pro</i>	 <i>Metashape</i>
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Cost	Pay-Per-Input License	Freeware	Free for limited use	Discount for a student license
Usability	Generating 3D data with a one-click setting	Partly need to control input value to increase the quality of data	Generating 3D data with a one-click setting	Providing procedural generation for 3D data and texture
Features	Easy to use, high-resolution texture, UDIM support	High customisation for settings, zero cost, UDIM support	Providing a wide arrange of data formats, low specification for the device	Providing various editing options for data, UDIM support, merging function
Data Processing	Local machine	Local machine	Cloud upload	Local machine
Limitation	Difficult to estimate the expected cost, High computation spec needed	The difficulty of manipulation of data generation, low stability	Shortage of handling option UI, not providing estimate timer,	High computation spec needed

Table 1. Comparison of photogrammetry application features

The second factor was the type of processing data of each application. In this comparison, local data processing was considered a priority for selection. If the application only provides online processing, such as cloud uploading, it could be difficult to handle data depending on internet access at the acquisition location.

As a result of comparing each program based on two conditions, *Meshroom* was the main application chosen, and *ReCap Pro* was considered useful to learn using photogrammetry software during the preparation.

4.3.1.2 Selection of Acquisition Equipment

I used two criteria for the selection of capture equipment for the 3D scanning process. First, as an essential factor, due to the location of the target being overseas and low accessibility, ease of transport was the initial point to consider for selecting scanning gear. That also includes the necessary training for using the equipment, the durability when carrying it, and ease of borrowing or purchasing if required. The next considerable point was the tool's usability and scale for a one-person team. There was expected to be only one operator: myself. Therefore, every piece of equipment had to be suitable to be operated with only one or two hands.

According to the above consideration, I listed necessary tools for the actual 3D scanning process (see Appendix 3). Still, I also had to list optional gear to replace items that would not be available on short notice. In fact, the camera and light were changed to a different model in the first acquisition phase. The reasons for that are described in section 4.4.1.3.

Besides capture equipment, computing devices for previewing pictures and generating preliminary results for quality control were required. Within this equipment category, the use of portable auxiliary data storage devices to back up the laptop and secure photographed images were prepared. Lastly, the laptop's specification needed to be sufficient to run the photogrammetry software, including a dedicated graphics card for viewing 3D data.

4.3.1.3 Selection of Scanning Targets

From the main concept of this research project, the aim of the VR content is not only focused on providing education about the traditional house, but also includes bringing an immersive playing experience as a narrative by integrating the cultural space and the cultural myths and legends. Following myths specific to Jeju island, the path of the user can be modified as specific areas are occupied by house gods. This intentional direction reduces the number of targets to be acquired to an amount that is manageable for the short-term journey: inner house, gate, inner yard, outer yard, and toilet. All of these targets are relevant as they are the main living places of the house gods.

According to the study of C.-H. Lee & Park (2014), *Choga* typically comprises of several constructional elements. The authors list the main components of *Choga* as wooden stilts, a floor, and two-layered walls. To be specific, the stilts are made of a wooden trunk with a root, which is erected upside down to resist strong winds typical for Jeju island. Also, for the same reason, *Choga's* wall is built with a mud and basalt mixture material. With respect to structure, these elements fall into two types of overall shapes: the wooden stilt exhibits a cylindrical shape, and the house walls a plane and box shape. According to this categorisation, preparation needed to focus primarily on 3D scanning of flat walls and cylinder structures.

4.3.2 Preparation

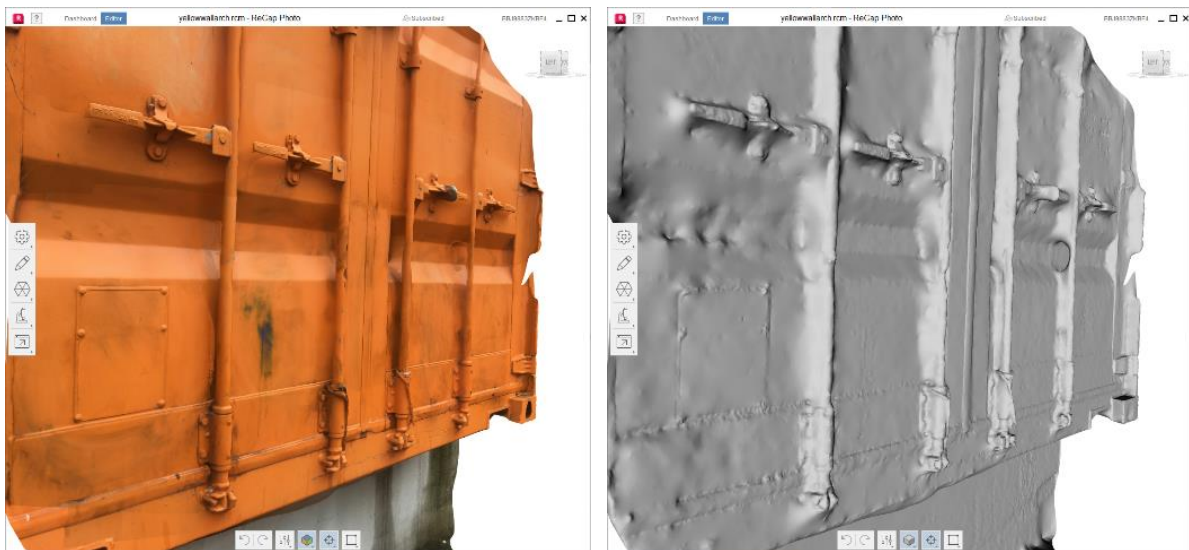
4.3.2.1 Process Familiarisation

As a selected method for the reconstruction of cultural heritage, the first step of the exercise is testing the photogrammetry workflow. In this stage, types of testing targets are separated for the specific digitalisation of the target object. According to the shape of the target of photo scanning, the approach to taking pictures is needed to change. Because this

traditional house has been constructed with various natural resources: e.g., a wall that is a mixture of mud and a wooden plate (Park, 2016), the shooting method also was expected to be executed differently for each texture. Furthermore, the reflections on the surface change due to this variety of the constructional ingredients.

Therefore, test shooting is executed by a division of objects as a flat surface, simple structure object and complex structure object. Data acquisition applications were carefully selected for each type. *ReCap* was used for flat and simple structure objects to check specific capturing path methods, and complex structure objects were chosen to compare photogrammetry software to decide on actual 3D scanning.

For my first experiment, I chose a the flat surface of a shipping container, which also had some protruding parts. Specifically, I tested two methods for the camera movement: arch line path and zigzag path. The 3D data reconstruction was executed in *ReCap*.



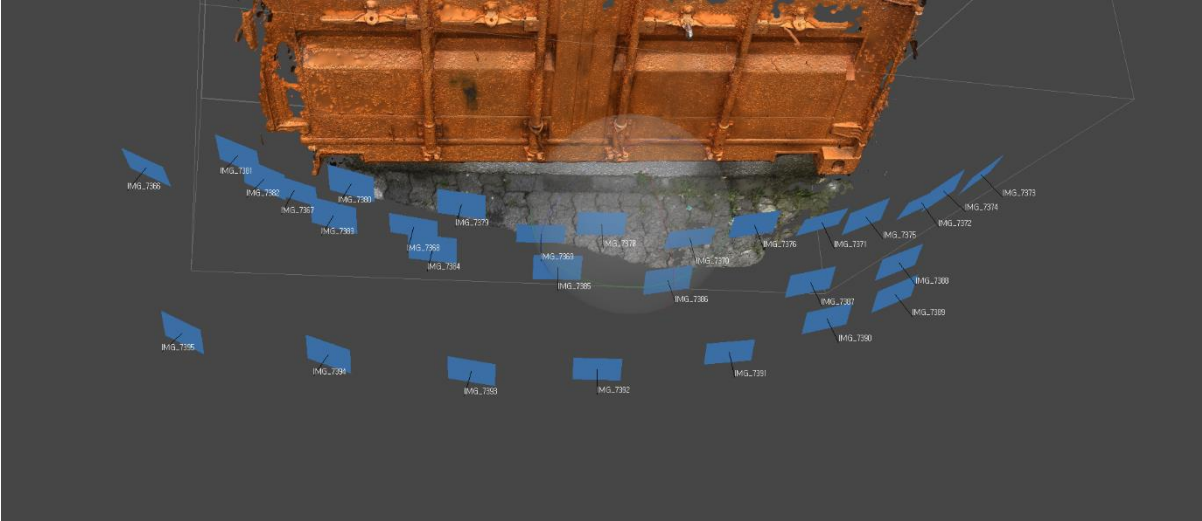
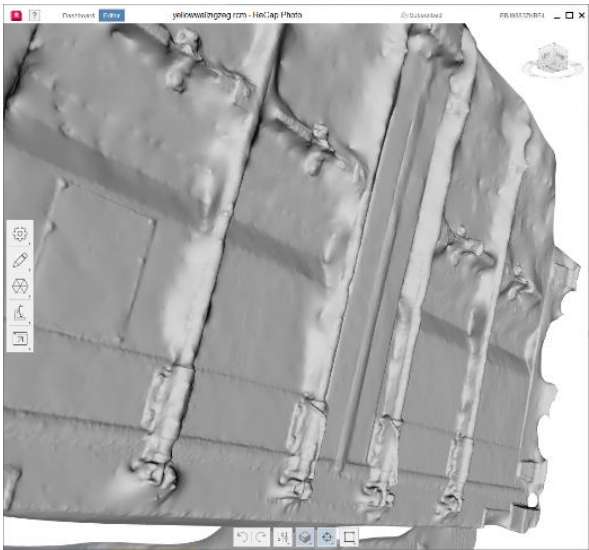
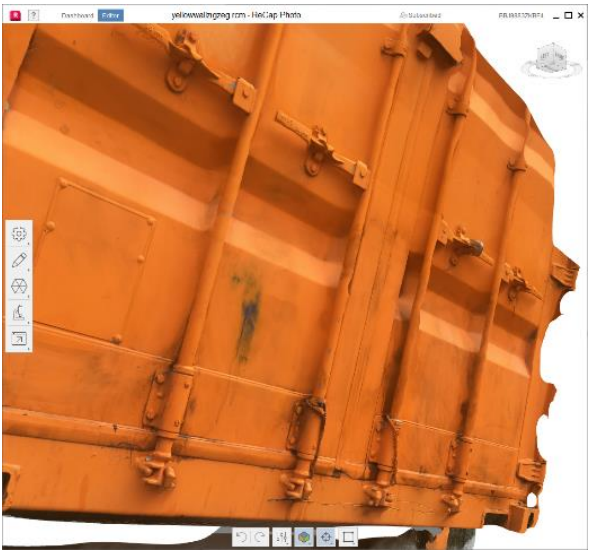


Figure 16. Capture of a flat target (container wall) using an arch-line camera path



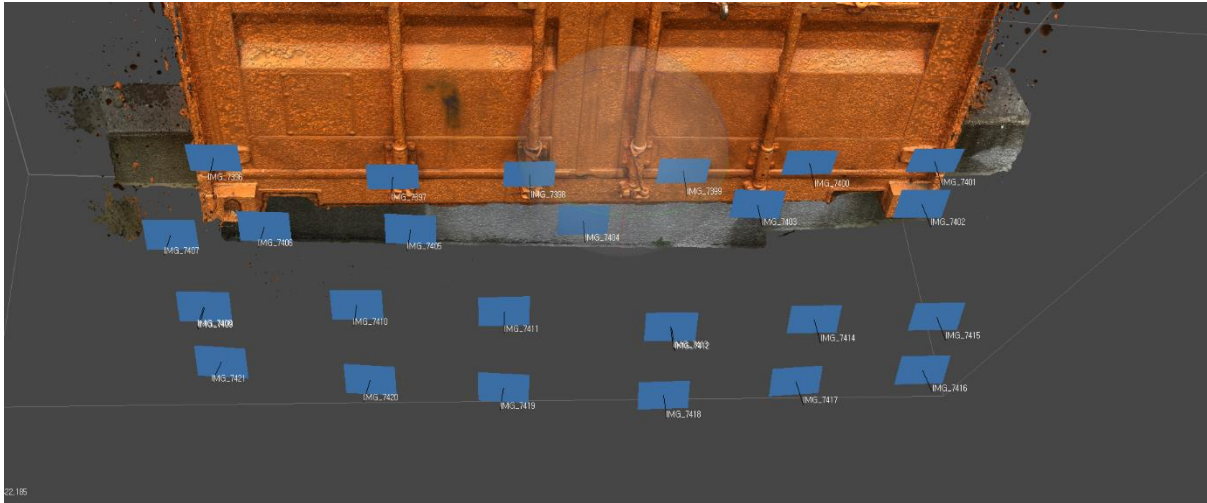


Figure 17. Capture of a flat target (container wall) using a zigzag-line camera path

With Texture mapping, both results of the photogrammetry process showed similar quality (see Figure 16 and Figure 17). However, when analysing the generated 3D mesh, the zigzag path method had resulted in a more regular and clean structure as well as fewer holes on its surface.

To test simple structure objects, I captured cylinder and box shape objects. For this, I used a circular path and a dome path. In addition, different surface qualities were selected such as reflective surfaces and diffuse surfaces for testing texture generation in ReCap.

For cylindrical objects, I chose a drink can and a wooden trunk as targets to generate 3D scanning data.

In the data acquisition process for the can, the shape of the mesh showed enough similarity with the target object. However, it also exhibited abnormal results on the texture generation because of the reflections on the surface (see Figure 18).

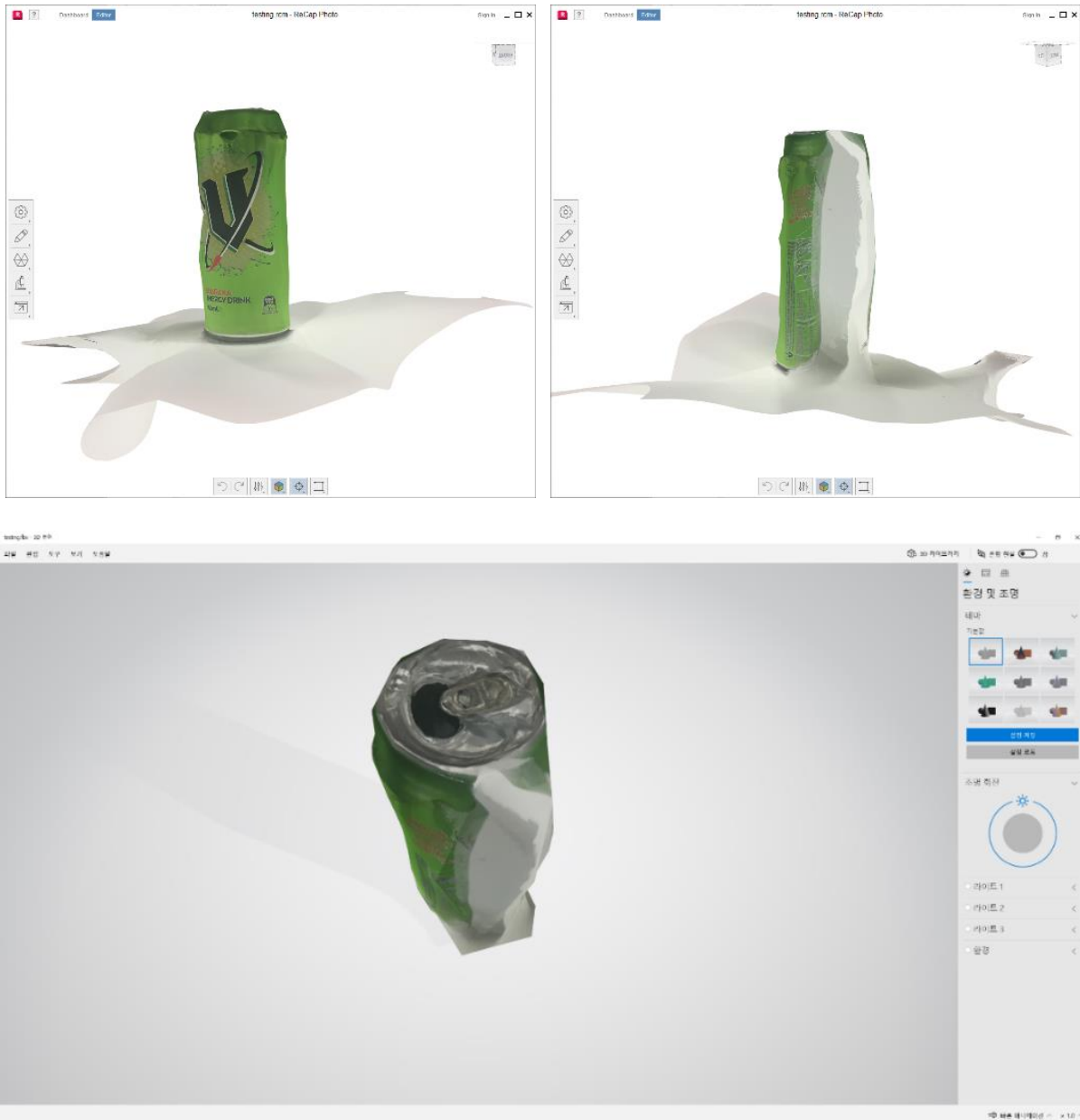


Figure 18. Capture of a cylindrical reflective target (drink can), using a cylindrical capture path

For the half-cylindrical data collection test, I chose a roadside tree trunk to scan using a half-cylinder camera path. The resulting texture of the tree had more detail than I had expected and a good quality (see Figure 19). This is probably due to the low reflectance of the tree texture and the shape and colour of the tree bark serving as a good reference when comparing specific point groups between photos. In addition, since it is a natural object that can have various shapes, even slight distortions are not noticeable, and details appeared better compared to man-made products.

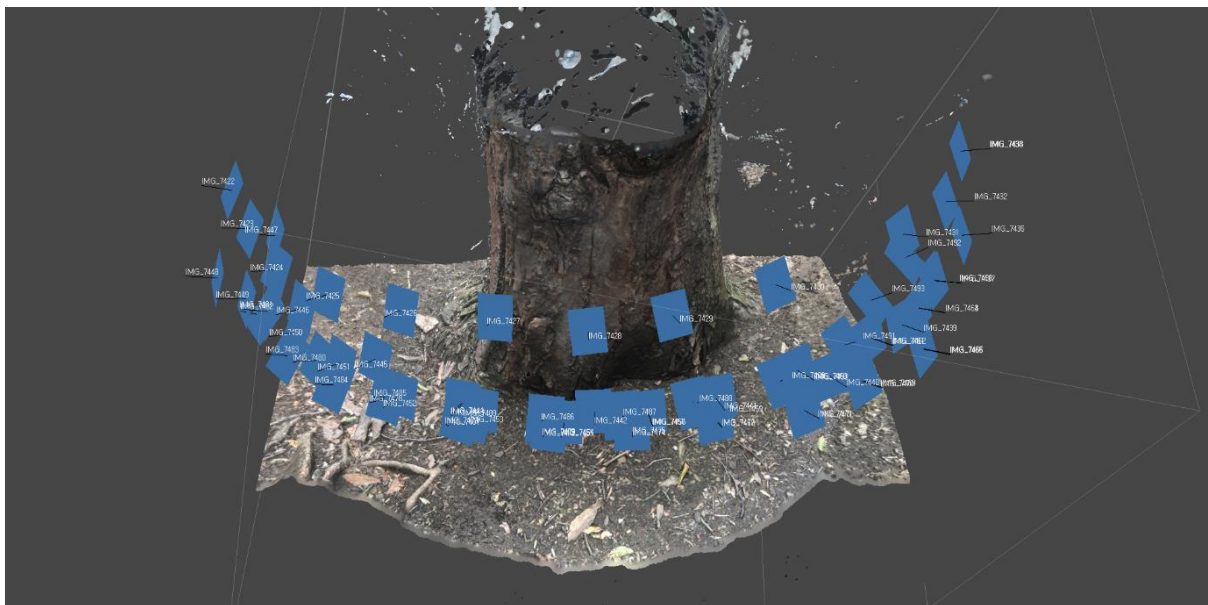
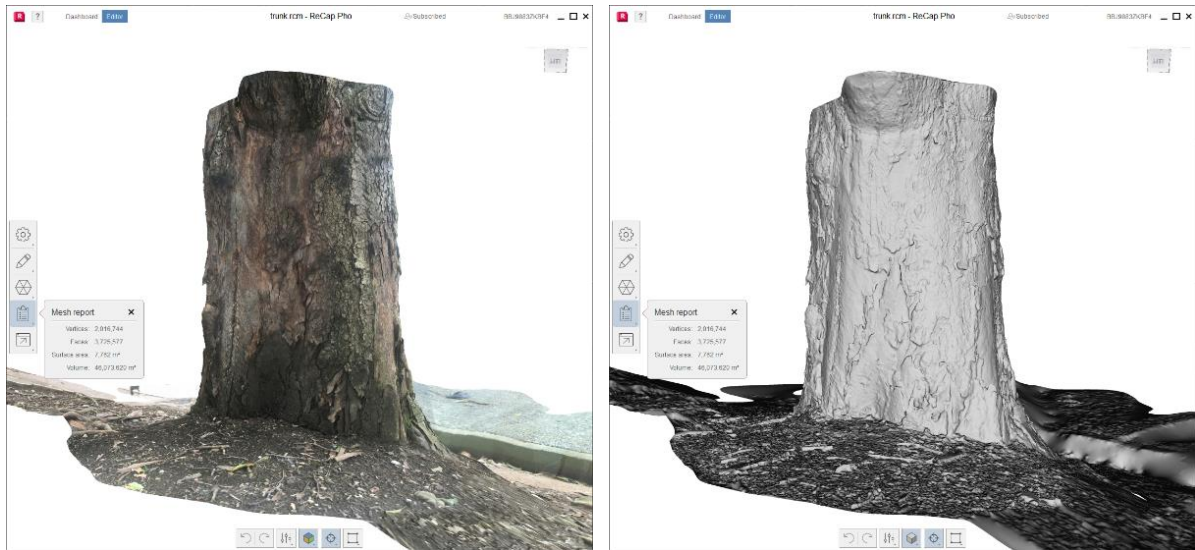


Figure 19. Capture of a cylindrical diffuse target (tree trunk), using a half-cylinder camera path

For capturing a rectangular shaped target using a dome camera path, I chose a bench in Aoteroa Square due to its mixture of wood and stone textures. I also expected to check the coverage of not only the target object but also the ground texture. The resulting model (see Figure 20) had better accuracy compared to the drink can, but lacked details of the underside parts of the bench, and the mesh had some holes and merged shapes.

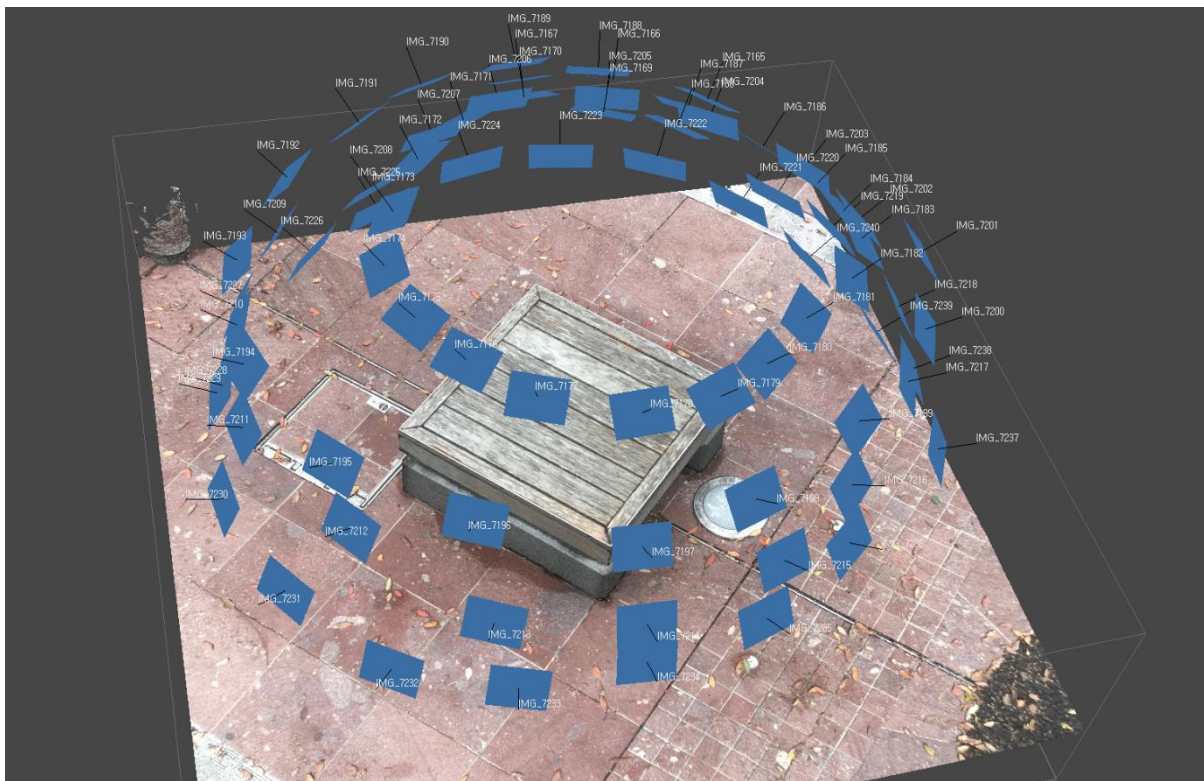
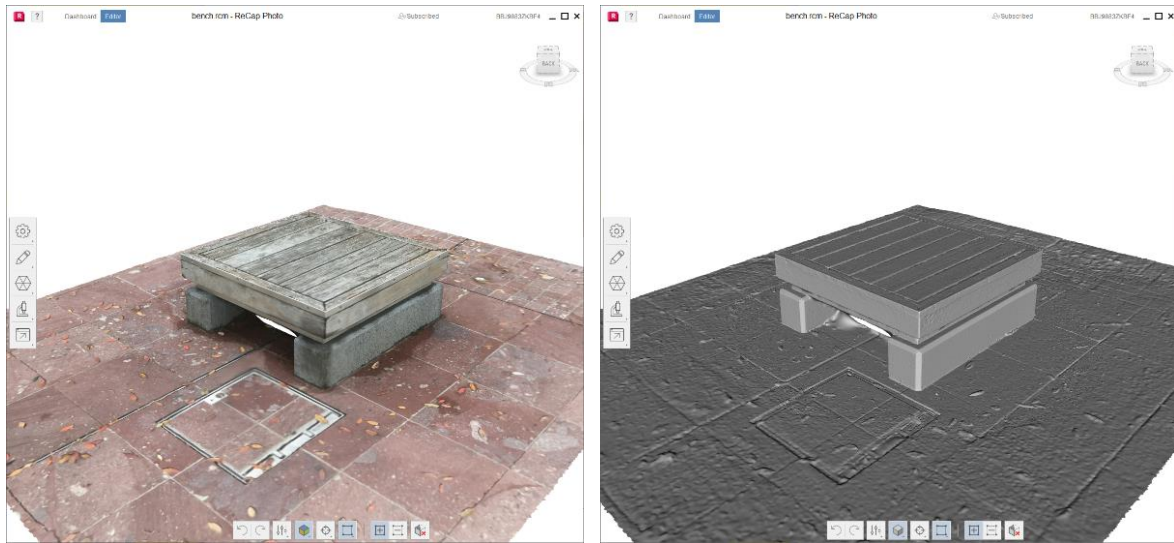


Figure 20. Capture of a box-shaped target (bench), using a dome camera path

According to the complexity of the target object, the shooting angle of the pictures needs to set very specific to improve accuracy. Also, the quality of the 3D model of the scanned object depends a lot on the resolution of the surface texture. With this in mind, I chose a mangrove tree to test acquisition of a complex shape (see Figure 21). I also chose this dataset to compare two photogrammetry application candidates (*ReCap* and *Meshroom*) to select the one I would use in the first acquisition phase.

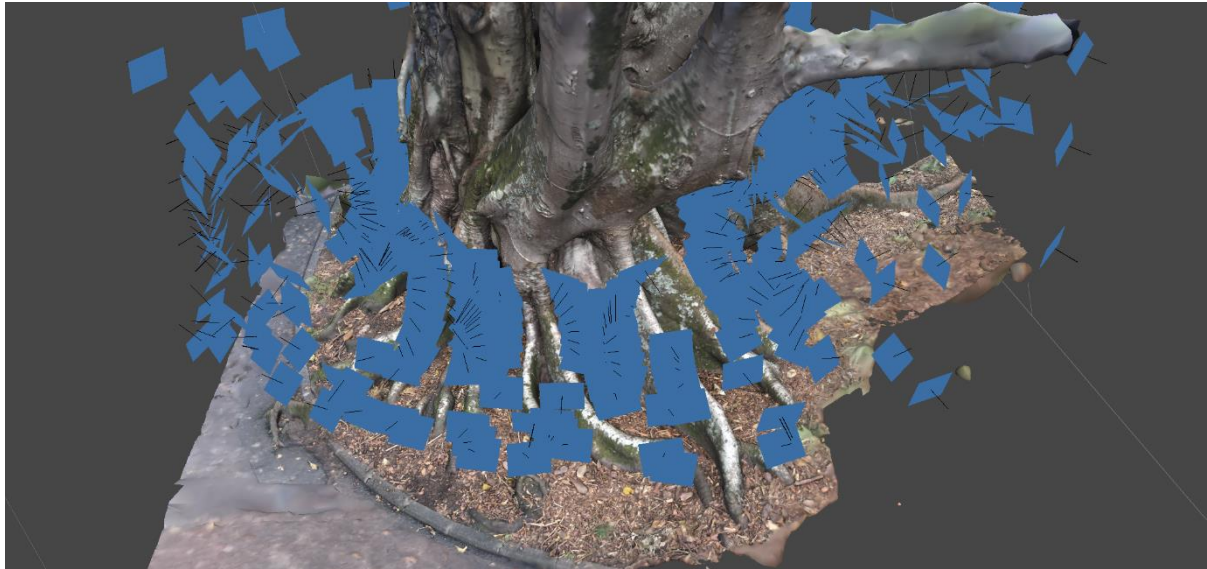


Figure 21. Camera path for capture of a complex object (mangrove tree)

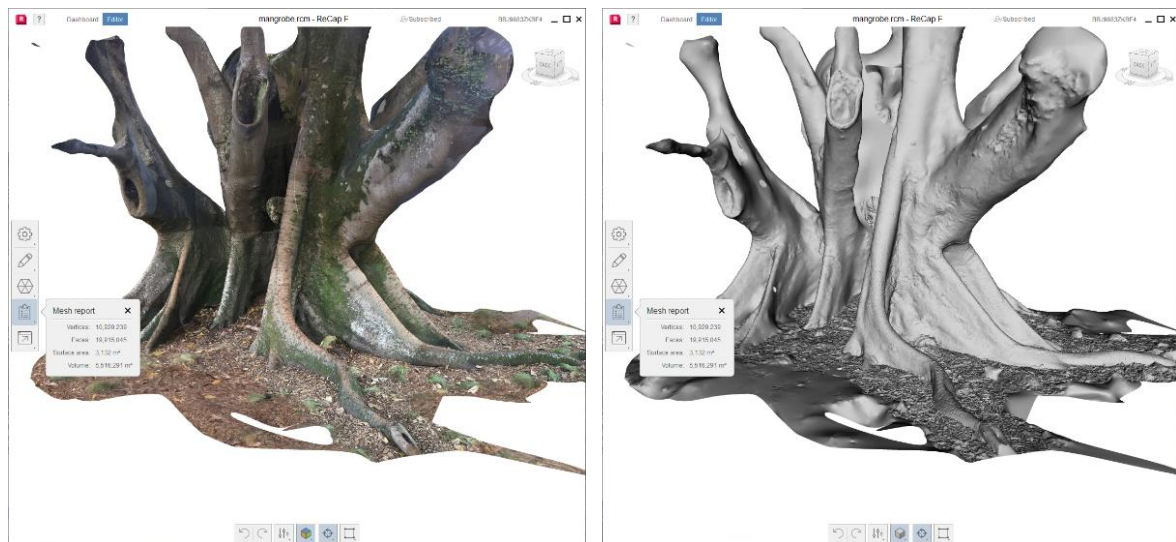


Figure 22. Capture of a complex target (mangrove tree), using a complex camera path, reconstructed in ReCap

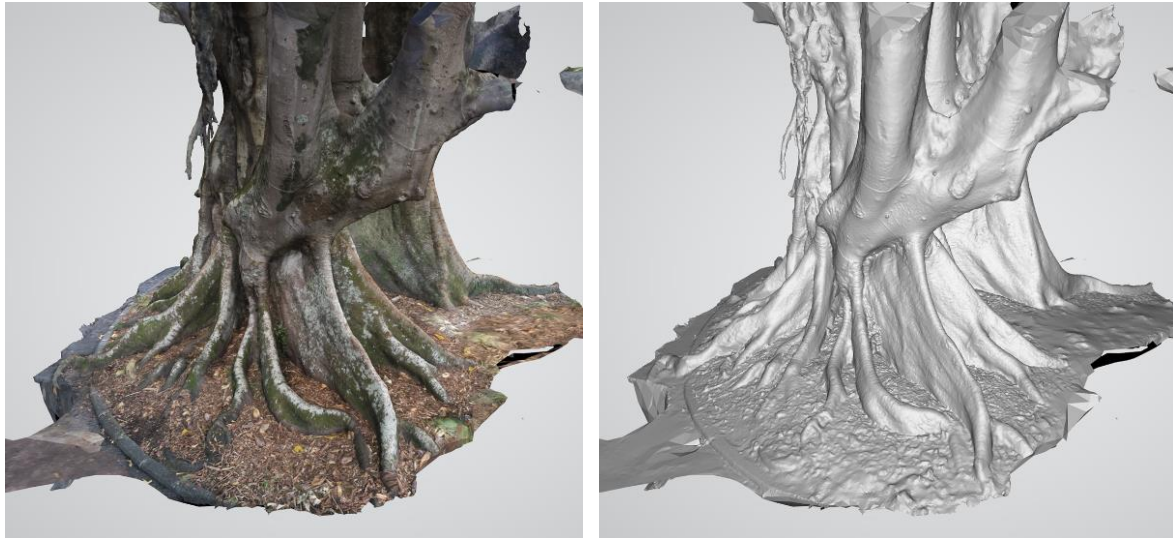


Figure 23. Capture of a complex target (mangrove tree), using a complex camera path, reconstructed in *Meshroom*

From the comparison between *Recap* (see Figure 22) and *Meshroom* (see Figure 23), the overall look of the results was similar, but when examining the polygon structure in more detail, I discovered that details of small parts on the model were missing and the generated texture had gaps.

In the end, I selected *Meshroom* as the main photogrammetry application for the first scanning phase because of several reasons. First, it is freeware. Second, *Meshroom* supports exporting 3D models in the OBJ format, a text-based, open file format which has gained widespread adoption by other vendors of 3D graphics applications, allowing it to be imported and exported by multiple software programs (McHenry & Bajcsy, 2008). Third, only *Meshroom* is capable of exporting textures in a multi-texture format called *UDIMension* (UDIM), a texturing system that arranges images into tiles, enabling the use of multiple lower-resolution texture maps for neighbouring surfaces, resulting in a higher resolution output without the need for a single, ultra-high-resolution image (UDIM Workflow, n.d.).

Additionally, *Instant Meshes* and *xNormal* were chosen candidates for the extra modification process. These applications support the specific workflow of modifying the retopology stage and texture baking. However, texture baking was expected to be implemented with *xNormal*, but it was not utilised, and *Blender's Cycles* renderer was used instead. *Cycles* is a physically-based path tracer utilised for production rendering that is intended to deliver physically-based outcomes without requiring extensive customization. Additionally, it features flexible shading nodes and artistic control to accommodate a wide range of production requirements (Introduction — Blender Manual, n.d.). Moreover, in addition to its

basic rendering capabilities, *Cycles* is the only renderer provided by *Blender* that offers texture-baking functionality. As a result, it was decided to use *Cycles* for texture baking, an essential part of the retopologising process that involves converting high-polygon count data to low-polygon count data and modifying 3D data.

4.3.2.2 Equipment Preparation

Because of the remoteness of the acquisition location, I had to select equipment based on how easy it is to be transported from overseas and how easy it is to rent in Jeju island.

According to the scanning test results described in the previous section, I categorised essential 3D capture equipment into three categories.

1. Actual capture equipment:

In the first data acquisition stage, the Digital Single-Lens Reflex (DSLR) camera was the primary scanning device. However, given the challenges in accurately predicting the distance between the target and camera location, it was imperative to have the capability to mount various lenses or adjust the focal length on the DSLR for optimal data acquisition. Therefore, combining two lenses, including a standard type and a wide-angle lens, allowed me to leverage their characteristics effectively. The precise specifications of these accessories are further explained below.

2. Camera accessories:

Technically, a lens's standard focal length is 35mm, originating from a traditional film format. For the above reason, there are cases where camera calibration or the image alignment processes for 3D scanning data collected need to be adjusted with reference to 35mm. Therefore, the selection of lenses for the camera was focused on models that could accommodate a focal length of 35mm. In addition, there was chance of encountering reflections on the surfaces of the target caused by sunlight, wet conditions, or metallic surfaces. For those reasons, it is recommended to use a polarising filter on the lens and/or the lights to reduce reflections of the target (Apollonio et al., 2021). Moreover, a tripod was required to avoid camera shake while shooting to achieve sharp and focused images during capture.

3. Lighting tools:

During the data acquisition process, environmental lighting significantly impacts the quality of scanned images and as a consequence the photogrammetry applications ability to reconstruct the 3D structure. It is crucial to pay special attention to lighting and

colour, particularly when capturing images for virtual reality (VR), as these factors can affect the overall quality of the VR experience. Additionally, Dhanda et al. (2019) emphasise that it is significant that, even though the photogrammetry capture process for VR is similar to the measurement for a metric survey, special attention needs to be paid to lighting and colour. The team suggests that images must be lit with diffuse, even lighting and recommends using a colour calibration chart to ensure accurate image quality (see Figure 24). Based on the deliberation above, I chose a pair of light sources that fulfil these objectives, namely a broad-ranging production light and a restricted-focused ring light.



Figure 24. Lighting setting of Myin-pya-gu fieldwork (adapted from Dhanda et al., 2019)

I split the equipment from the three aforementioned categories into two groups, based on their mobility, stability, rental efficiency, and the country where the target cultural heritage is located. One group consists of equipment that I would bring with me from New Zealand, while the other group consists of equipment that I would rent and transport within Korea.



Figure 25. Selected capture equipment. The items within the red line were transported from New Zealand to Jeju, while the items within the blue line were rented or purchased locally.

Among the equipment listed in Figure 25, the DSLR camera, a Canon 70D, and a standard 24-70mm zoom lens (items 1 and 2 in Figure 25) were deemed the most important equipment in the data collection process due to their portability. Therefore, they were requested from my university department. As shooting conditions can change on the heritage site, a wide-angle lens (item 3) was rented in Korea for auxiliary use. In addition, LED light (item 4), camera tripods (item 5) and reflectors (item 7), which are difficult to transport from overseas due to their size and/or weight, were also rented locally. Furthermore, the camera-mounted ring light (item 6) and polarising filters (item 8), which were not available for rent at my university, were purchased locally.

Finally, before visiting the target site for 3D scanning, it was important to reconfirm the prior approval from the administrative agency responsible for managing and operating the cultural heritage. This involved coordinating with the agency regarding the availability of the capture equipment and lighting, obtaining permission for the use of electrical facilities, confirming

their location, and clarifying potential liabilities that may arise when entering cultural festivals. A research visit request form was submitted to the agency to specify these matters, and it is included in Appendix 4.

4.3.3 Acquisition (9–14 Dec 2019)

4.3.3.1 Planning

For the acquisition trip, I expected modifications to the original plan for the heritage data collection due to unforeseen circumstances in and around the actual environment. In order to address this, my plan had a certain flexibility around the main steps, like agile development.

In Korea:

- Borrowing certain equipment (light, lenses, ladder, cables and batteries) from the rental shop, the Association of Media in Jeju, and the museum.
- Organising additional equipment such as a secondary camera and a tripod.
- Re-checking for permission to enter and capture the target location via communication with the heritage village office

In Jeju:

- Taking pictures of the target objects
- Quick reconstruction and render to check for a good photogrammetry outcome
- If necessary, choosing additional resources for extra shooting
- Looking for substitution targets and additional objects (house 3, stone wall, sub-objects)
- Having a meeting with the cultural researcher and getting advice for more accuracy.

The external and internal surfaces of the traditional house of Jeju require different settings for taking photos. Achieving a high texture and mesh quality with photogrammetry needs controlled factors based on the surface characteristics of the target and the environment.

The weather condition is a primary factor for outside scanning of a target. In the photogrammetry process, uniform lighting highly influences the performance of texture creation and the generation of the shape of the object. The surrounding environment of the target resource also has the potential to affect the result as the source of reflected or occluded light. Nevertheless, it can be difficult or impossible to control this aspect of lighting of the target depending on its size, volume, and location (Unity Technologies, n.d.).

The main factor for inside scanning is setting up artificial lighting, especially in this case as there was no additional light for the sake of preservation of the original nature of the traditional house. In this phase of internal shooting, a certain distance is required between the target object, the light resource and the position of the capture gear.

4.3.3.2 Acquisition Process



Figure 26. First impressions of the traditional house *Choga*

The actual environment (see Figure 26) is challenging to control, even though I had done preparation and investigation for a smooth capture. The capture process was focused on surface-based scanning of exterior features such as walls, roof, etc. Additionally, each scanned object was intentionally given some overlapping parts on the borders of 3D models for the later stitching phase. The order of the scans was from the external surfaces of the main house to the internal spaces, from the main house to the sub house.

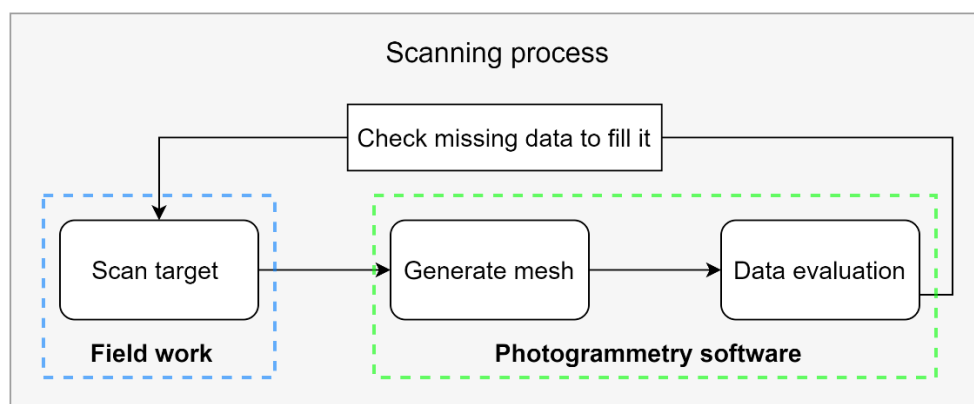


Figure 27. Workflow of the first scan process for *Choga*.

Scanning was implemented in two stages: data collection from the fieldwork during the daytime, and data evaluation in the photogrammetry application in evening. In the first step, data collection of the target objects was performed in a systematic pattern, having dividing the target into zones. In the second step, data verification was required since the daytime capture was done without a device to allow for quality control of each scanned model, e.g., by generating point clouds (see Figure 28). Based on the results of this quality control, I was able to adjust the scanning plan, e.g., adding re-scanning passes to fill in missing data. However, due to insufficient computing power of my equipment (two laptops), I was unable

to check every dataset. Once back in New Zealand, when every dataset had been processed, I found more missing data, which I was by then unable to reacquire and which increased the time necessary to process the models.

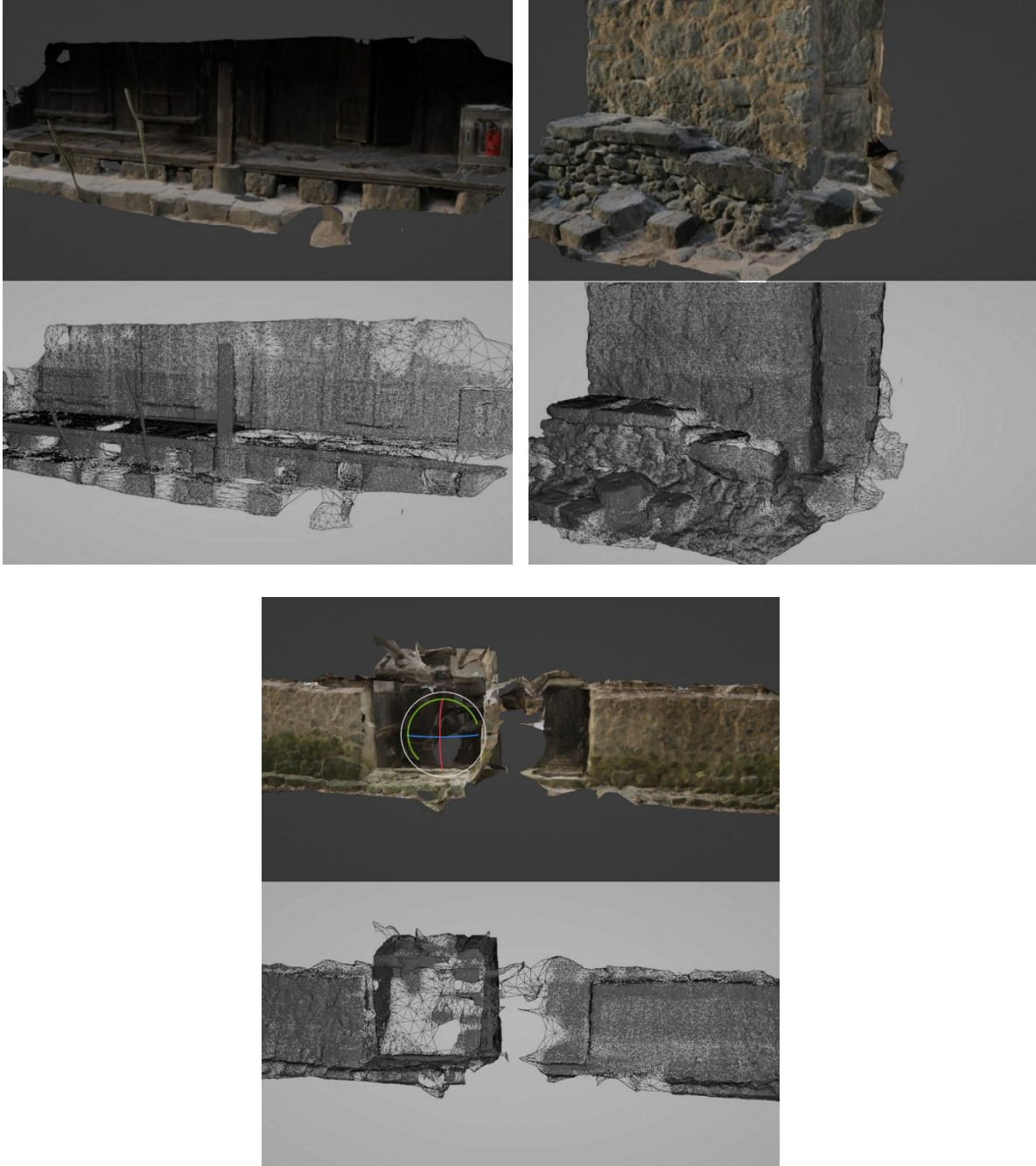


Figure 28. Generated meshes in *Meshroom*. Each image has two modes: texture view (top) and wireframe view (bottom). In Wireframe mode, partially non-uniform polygon density can be observed. While the texture overlay may give the impression of high quality, caution is needed when extracting normal maps, as lower polygon density meshes can result in lower-quality outcomes.

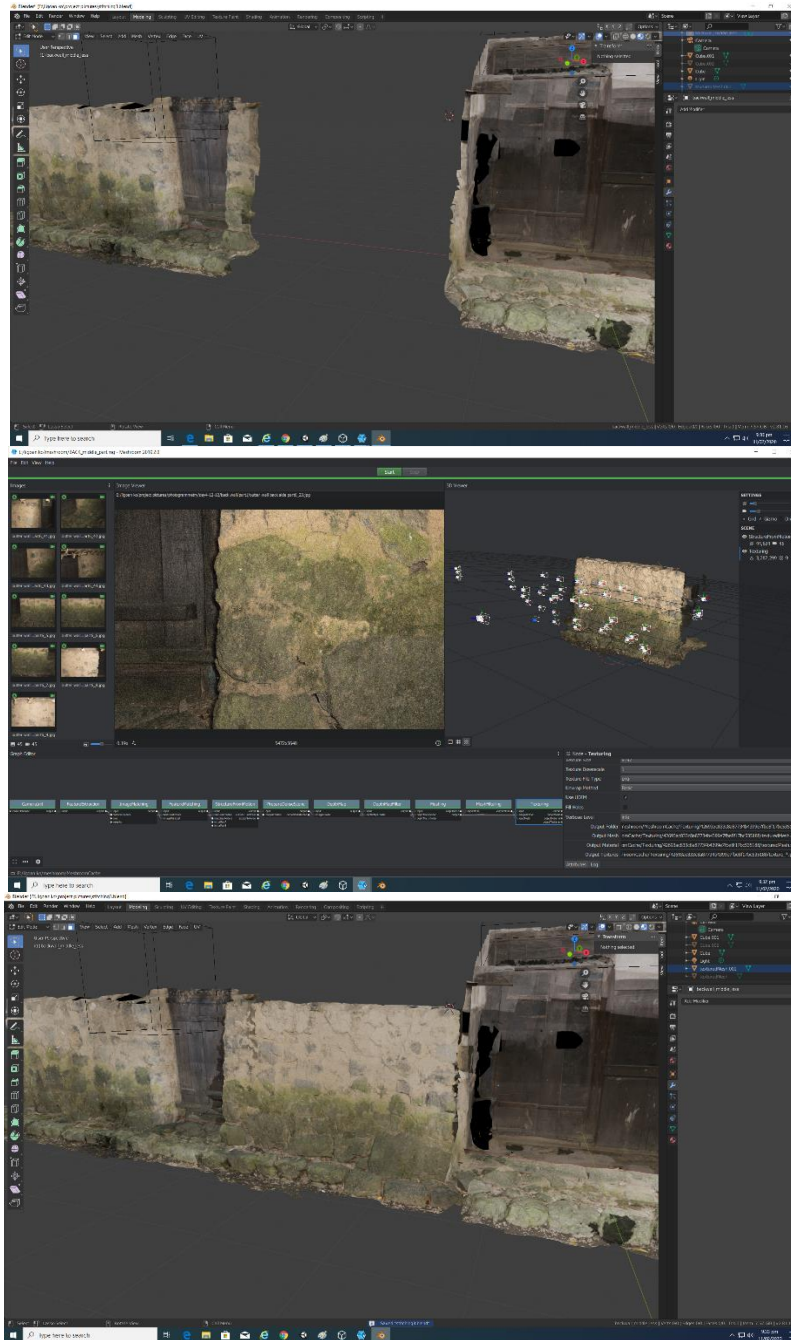


Figure 29. Filling in missing parts of the scanned data. The top image shows lost part of the *Choga* from data generation. The middle image indicates re-generating of missing part with extra data acquisition. The bottom image is stitching result of both data in *Blender*.

Filling in missing surfaces of the scanned data was done in *Blender* because *Meshroom* does not provide a merging function for scanned models (see Figure 29). Even though errors in scale matching for the whole place could be expected, matching geometry was done by hand for each small part before the stitching stage.

4.3.3.3 Problems

Despite the fact that the acquisition process was planned and verified based on the blueprint of *Choga*, the following problems occurred in parts of the target.

Shooting distance:

Certain sides of the scanned target did not provide enough distance to take a photo, e.g., caused by rock walls or trees obstructing line of sight or preventing the positioning of the tripod (see Figure 30).



Figure 30. Walls and trees obstructing camera placement.

This problem caused a lack of merging borders for each generated 3D mesh. In addition, it affected scanning all of the shapes of the target house at one shooting time. Even though shooting planning was already set for separating and stitching surfaces, the insufficient spacing caused abnormal seams due to the automatic interpolation of the texture generating process of the photogrammetry application. Also, this issue caused lost mesh information for a roof of the target house caused by the low capture angle, preventing accurate surface reconstruction.

Interior space access restrictions:

After arriving at the target site, I was informed that a particular internal space was restricted from entering. This was caused by miscommunication between the executive and management departments of Seongeup Historic Village. This issue resulted in reproduction difficulties due to extremely limited angles (see Figure 31) and a necessary change of plan to later manually create the unscanned pieces of the target house (see Figure 32).



Figure 31. Limited capture angle and positioning for interior acquisition

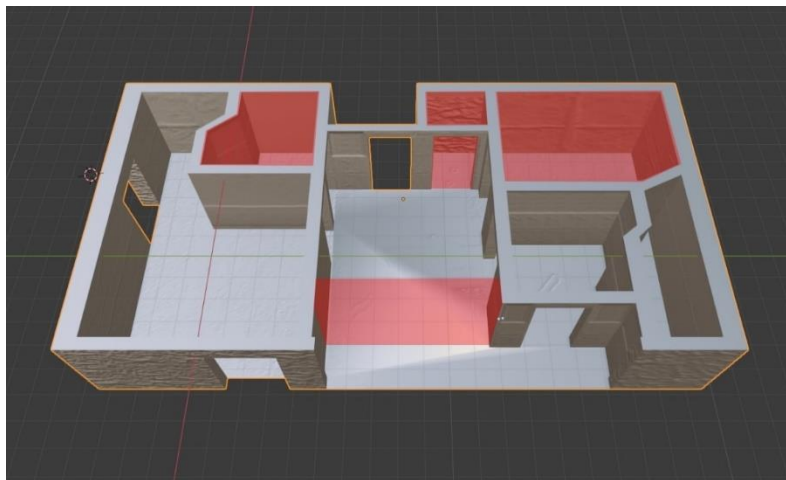


Figure 32. Areas not accessible due to site restrictions

Pollution:

The fact that the target site is regularly open to visitors is convenient for my task of scanning the external surface of the target houses, but it also has the side effect of encountering pollution by garbage (see Figure 33).



Figure 33. Example of garbage (green wrapper) and sticks left by visitors in the capture area

Loss of objects:

It was anticipated that obtaining consistent data from additional shooting might not be possible, as many objects are damaged or disappear due to the open space being easily accessible to a large number of spectators. In fact, during the visit in 2022, the pottery pieces that had been placed outdoors and were already damaged in 2019 were found to be missing (see Figure 33).



Figure 34. Loss of one traditional vase at the target location between 2019 and 2022

4.3.3.4 Change of Planning

During the data evaluation and rescanning of the target place, mesh generation failed in certain parts of the house in the photogrammetry application. Among the missing geometry was the roof, which I decided to replace with that of another house. The roof of a traditional house in Jeju is mainly made from straw and usually fixed with a checkerboard rope-pattern (C.-H. Lee & Park, 2014). Since it is also common to be changed every year by the residents of the village, there was no high importance to preserve the exact detail. A replacement for the roof was acquired from a similarly scaled house in Jeju Stone Cultural Park (see Figure 35 and Figure 36). However, the result of the mesh generation showed an incomplete

In addition, extra items were scanned for this project, such as *Jeongjusuk*, a part of the traditional outer gate (see Figure 38), small rocks as components on the ground (see Figure 39), and ritual shrines and traditional totems on Jeju island (see Figure 40 and Figure 41).

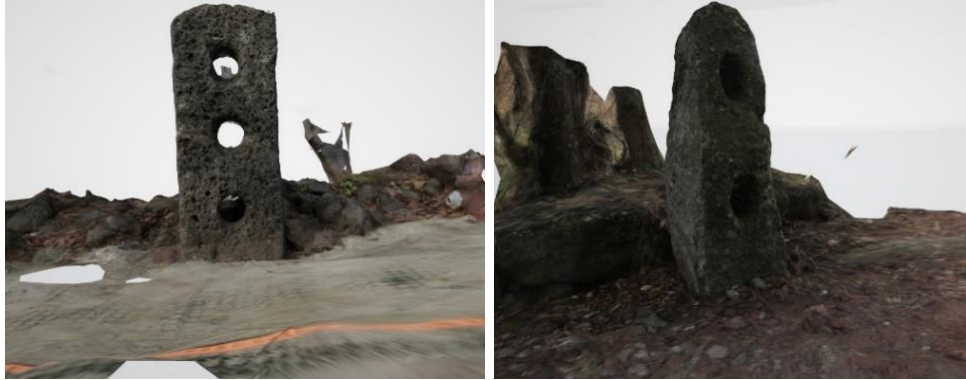


Figure 38. 3D scan of *Jeongjusuk* (part of outer gate)



Figure 39. 3D scan of miscellaneous stones and a rock wall



Figure 40. 3D scan of a ritual shrine



Figure 41. 3D scans of totems

4.3.4 Data Processing Workflow

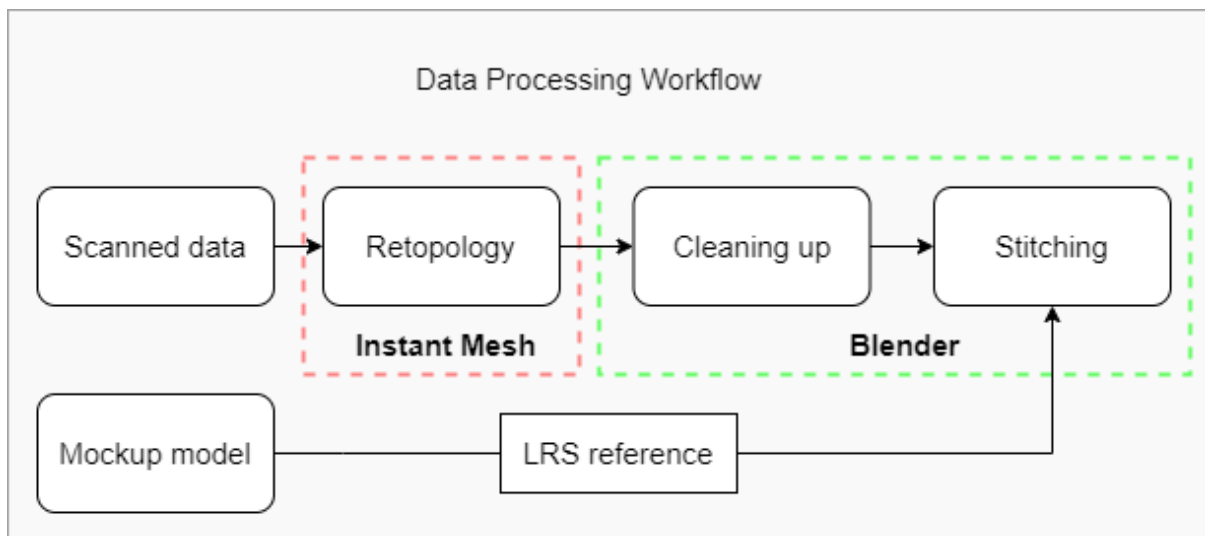


Figure 42. Workflow of data processing for the photogrammetry data

The workflow for processing the scanned mesh data consists of three steps, explained in more detail and with some examples in the following subsections. First, each mesh was run through *Instant Mesh* for the retopologising process to reduce the polygon count. This step decimates a high-poly model to a low-poly model, a necessary optimisation for using the data later in the game engine Unity. Besides, this process also provided advantages for cleaning up and filling holes on the surface. Second, the retopologised data was cleaned up and holes were closed in *Blender*. Optimising textures through a process called “baking” was also a significant step necessary for the later import into the game engine. The third step was stitching the processed meshes based on the mockup model as a reference for each partial mesh’s location, rotation and scale (LRS).

4.3.4.1 Retopology

Every scanned mesh had to be retopologised in *Instant Mesh*. This process aimed to simplify models by reducing each data's polygon count and decimating its mesh formation. This data optimisation also simplifies the process of UV mapping in the modelling program and improves the performance in the game engine, therefore preventing jitter while viewing it in a VR headset. Figures 43, 44 and 45 are examples of the retopology workflow. The target object, *Jeongjusuk*, which is part of the traditional gate, was converted from a high-poly model to a low-poly one (see Figure 46). As a result, the object's poly-count decreased from 195,387 down to 2,380, while still maintaining the original look with the detail of the surface and structure being incorporated into the normal texture map.

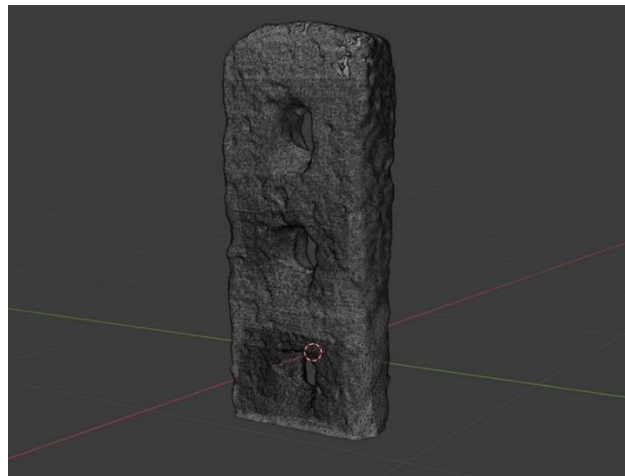


Figure 43. High-poly wireframe of *Jeongjusuk* before retopology

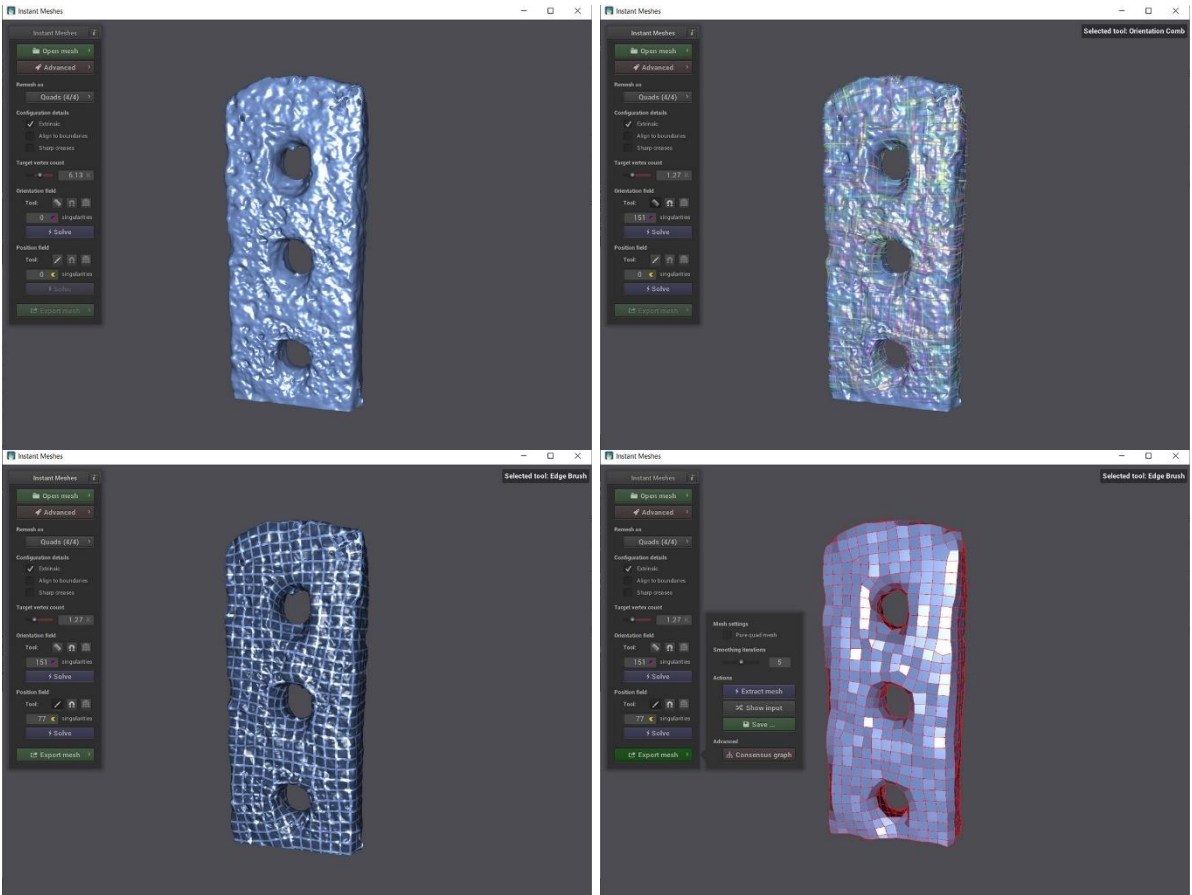


Figure 44. Retopology process of Jeongjuseok in Instant Mesh

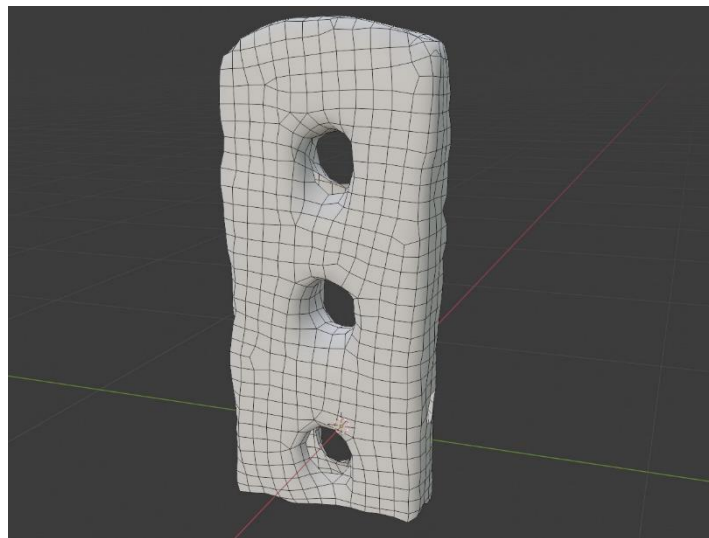


Figure 45. Low-poly wireframe of Jeongjuseok after retopology

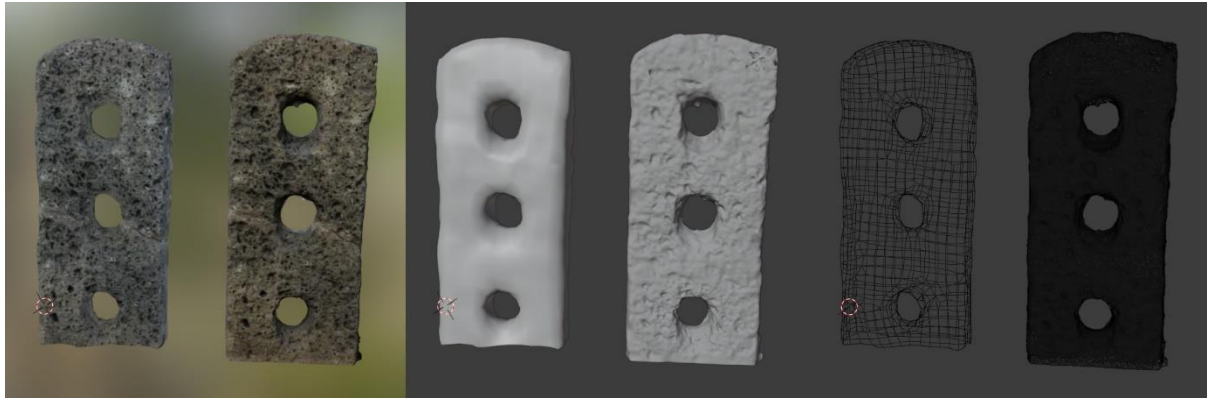


Figure 46. Comparison between the low-poly model (left) and the high-poly model (right) of *Jeongjusuk* after retopology and texture baking

4.3.4.2 Restoration and Mesh Cleanup

As described above, mesh cleanup was the following step after retopologising. It can often be observed that generated 3D models have lost parts on their surface caused by lighting, capture angle or data acquisition issues in the photogrammetry application (see Figure 47). I used the face edit mode in *Blender* to fill any holes in the mesh (see Figure 48).



Figure 47. Example of holes in the high-poly mesh

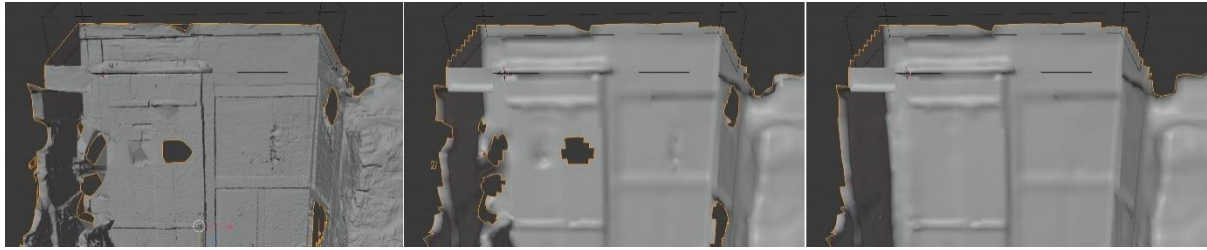


Figure 48. Examples of cleaning holes in a door mesh in Blender

4.3.4.3 Stitching

After finishing the cleanup process, the meshes were assembled based on the geometry information of the initial mockup model of *Choga* (see Figure 49). It was reasonable to match the scale with the mockup because the model was built with a blueprint from a measurement of a real traditional house in the target site. First, I matched exterior scanned objects with the geometry information of the mockup. For a while, there was an extra step for reproducing a large proportion of missing parts via direct hand modelling according to measurement if it was impossible to extract those from scan data. Texture data for these parts was borrowed from existing scanned data or pictures from the scanning phase.

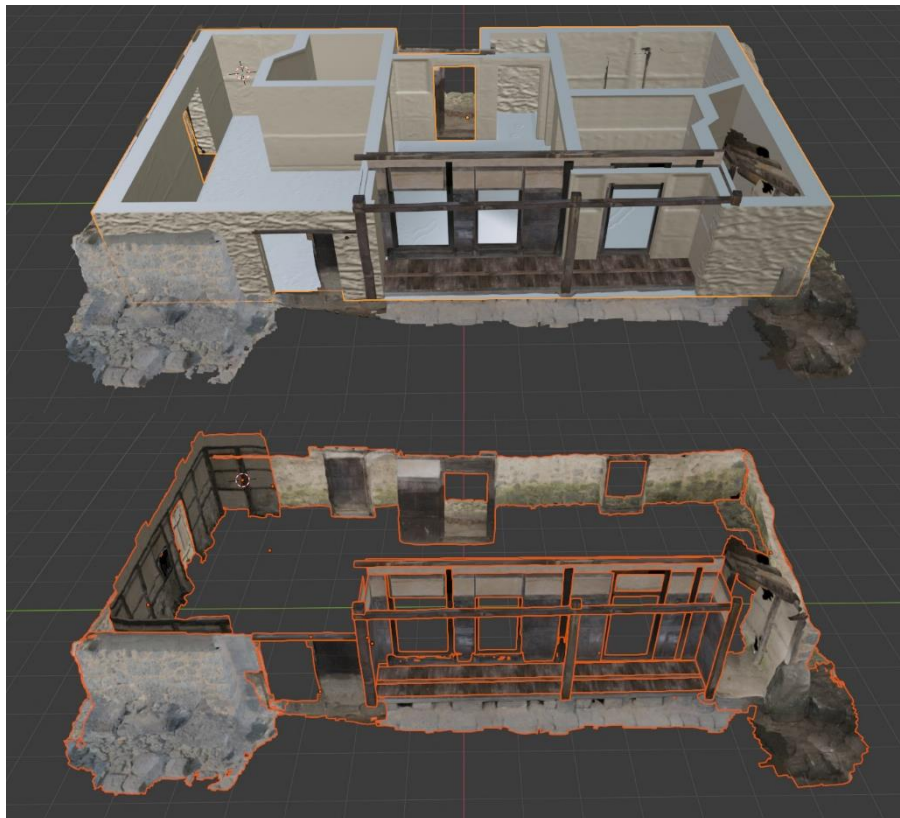


Figure 49. Stitching exterior mesh parts with the help of the mockup

In the progress of stitching the interior parts of the main house (see Figure 50), more manual modelling was required than for the exterior data as a result of the access restrictions to the interior (see Figure 51). The master room and inner storage were completely missing. Also, one side of the living room was incomplete due to the limited capture angles.

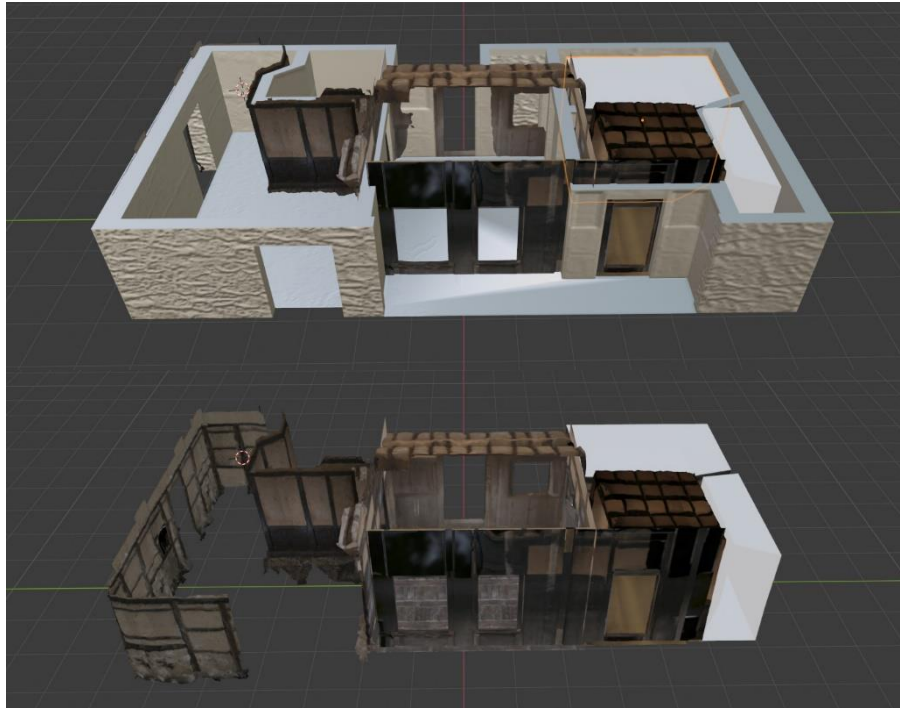


Figure 50. Stitching interior mesh parts with the help of the mockup



Figure 51. Areas of manual modelling



Figure 52. Exterior and interior models combined

Finally, except for missing parts, the cleaned and stitched meshes were combined (see Figure 52). Among the missing parts, specifically the inner spaces such as the storage area, I was unable to verify the look and structure against the original due to the restrictions during the capture phase. Therefore, to create the inner storage (the white parts in Figure 52), I followed a reference to the existing structures of another traditional house in Jeju. During the cleanup of the data, I had split and rebuilt active objects such as doors to give them thickness.

The main house model was temporarily finished with the roof polygon model (see Figure 53). I also created 3D objects for other missing parts of the overall *Choga* site, such as rock walls and *Jungmock*, the wooden pillars of the outer gate. Even though I was concerned about an unbalanced look between scanned data and manually created data, I decided that matching the tone with other game objects would be a priority from a level design perspective. Furthermore, more factors affected this design decision: time management and the sudden impossibility of a re-capture visit by the worldwide lockdown caused by the COVID-19 pandemic.



Figure 53. Finished model of the main house

4.3.5 Reflection on the First Acquisition Phase

Most of all, this first acquisition journey taught me that the 3D scanning process should always be designed to be flexible due to the various risks and obstacles encountered in the target location. It was necessary to be open and flexible for changes in the planning to react to unexpected events and discrepancies. In the pre-production stage, a shooting plan was designed with only remote information of the overseas target location. However, acquiring preliminary information alone was insufficient to control the on-site environment, resulting in unsolvable problems. Environmental factors such as weather and season were important, but also human factors such as (restriction of) accessibility to parts of the location, transport and import of acquisition equipment, and inconveniences such as visitors of the site simply walking through the picture were also crucial. Due to inconsistencies between the on-site and administrative management, there were unexpected situations where entry into a specific location was impossible, making scanning impossible. Despite the preliminary investigation, there were also problems where pottery, trees, and stone walls in the unscanned area of the site interfered with the scanning distance, angle, and lighting, causing data loss in locations such as roofs, indoor areas, and bathrooms. Additional cameras and auxiliary camera lenses, strong lighting, reflective plates, and ladders were prepared to counteract expected problems, but they were not user-friendly. Additionally, for unscanned sections of the site, textures were extracted from the scanned data with a similar texture and structure and added. However, a natural implementation was impossible for structures such as the thatched roofs. Ultimately, through an artificial reconstruction process, it was possible

to produce the missing parts, but it was not sufficient to fully implement the exact structure, and additional work and changes to my timeline occurred. I started considering LiDAR scanning, which can collect cloud point data of the subject regardless of the amount of light in the field, in addition to the photogrammetry process. However, at that time, it was impossible to bear the cost and mobility of the equipment, and the COVID-19 lockdown put a definite halt on any thought of revisiting the site, so I had to leave it at that.

4.4 Second Acquisition Phase

During the involuntary hiatus of my research, I thought about how to improve the process of the first scanning journey for my second phase. My second journey aimed to achieve better results with renewed data acquisition. During the planning, I adapted most workflows to prevent issues encountered on my last trip. Also, I ran tests with several applications and new equipment to clarify the data collection to improve my chances of achieving my goal. In this step, the usability verification of each application and the possibility of obtaining more advanced scanning results through a hybrid approach and a combination of applications were considered.

4.4.1 Planning

4.4.1.1 Modified Workflow for Hybrid Scanning

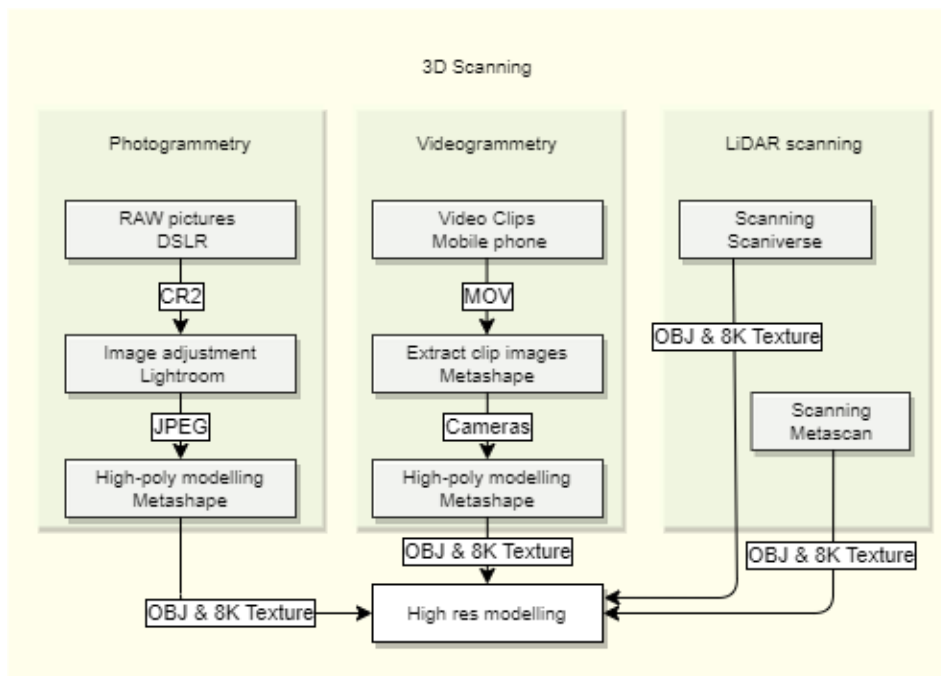


Figure 54. Modified workflow for hybrid scanning

While establishing a modified plan for my second acquisition workflow, reduction of missing data was my main focus. Having to edit the scanned models to add lost data affected not only the complexity of the data processing stage, but also added to the time needed, reduced the natural appearance of the model and with that the harmony in conjunction with other objects when combined all together within the game engine. For example, in the first capture of *Choga*, using my initial workflow, scanning the target site separately caused a lot of lost data due to the delay in checking the accuracy of the acquisition process. Therefore, I wanted to adapt the workflow to be able to capture the target site as a whole, so videogrammetry, a 3D acquisition method that uses continuous video footage instead of a set of photos (Torresani & Remondino, 2019), was considered as the main scanning method. Also, unlike in 2019, when dedicated LiDAR scanners were still somewhat costly and burdensome to use, the LiDAR scanning function integrated into iPhones by 2022 had evolved to enable personal use through mobile applications. Research by Luetzenburg et al. (2021) confirmed the potential for utilising mobile LiDAR scanning (MLS) applications to collect large-scale terrain data, confirming my decision to use MLS as a secondary scanning method. Existing data from the first acquisition phase was also ready to be used on specific surfaces that would need complex detail. My hope was that this hybrid combination of all three scanning methods would improve the result of my second acquisition journey.

4.4.1.2 Change of Photogrammetry Application

The selection of a photogrammetry application is strongly related to the design of the capture workflow. Therefore, even though *Meshroom* had demonstrated high accuracy in generating meshes during my first journey, I needed a substitute because of the specifications, better stability, and the processing needs for mesh generation via video clips. I chose *Metashape* for its usability, support of the necessary input formats, and the ability to merge data from my previous mesh generation processes.

4.4.1.3 Change of Acquisition Equipment

Through my first scanning trip, I learned that some equipment is necessary to cope with local conditions in outdoor work, but the ability of fast capture should also be considered to lower the chances of changes in weather and sunlight. Therefore, I chose to only use a mobile phone and some additional lightweight equipment as a very agile and mobile capture equipment. In addition, I expected to be able to simplify my lighting equipment due to the low light source dependence of the LiDAR scanner.



Figure 55. Capture equipment for videogrammetry and MLS (top left: iPhone 13 Pro, right: Handheld gimbal, bottom left: external LED light)

Specifically, I wanted a capture device that included a LiDAR sensor capable of mobile cloud point scanning technology. Fortunately, at this point in time (March 2022), Apple had developed a LiDAR sensor that was integrated in iPhone models starting with the 12 Pro model, plus corresponding mobile applications that utilised this sensor. As a result, unlike during my first acquisition phase, I expected that my personal new iPhone 13 Pro with its mobile LiDAR would resolve any issues I had with insufficient light when scanning indoor areas. Additionally, I expected that the resolution of photos and videos captured would be at least close to those of the DSLRs previously used, so I decided to make the mobile phone with the LiDAR sensor and inbuilt camera my primary acquisition device. The LiDAR sensor and camera specifications are listed in Table 2.

Phone Model	iPhone 13 Pro
-------------	---------------

Camera	Pro 12 Mega Pixels camera system (Main, Ultra Wide and Telephoto)
Lens	Main: $f/1.5$ aperture Ultra Wide: $f/1.8$ aperture Telephoto: $f/2.8$ aperture
Video output	4K video recording at 24 fps, 25 fps, 30 fps or 60 fps 1080p HD video recording at 25 fps, 30 fps or 60 fps
Advanced Features	Sensor-shift optical image stabilisation for picture/video
LiDAR capability	LiDAR Scanner included

Table 2. Specifications of the main capture device for the second acquisition phase

Additionally, I chose specific accessories to enhance the quality of data acquisition. Since I might re-encounter restricted access areas like in the previous data collection process, a gimbal with a telescopic extension feature was considered to widen the scanning angle as much as possible. A compact gimbal from DJI was chosen instead of a large camera gimbal to accommodate the mobile size. Furthermore, even with the LiDAR sensor, targets may require additional light, so I organised an LED auxiliary light with a brightness of 800 Lux. With these three types of accessories, including the gimbal, the extra light, and the mount to combine them, I conducted the data collection process.

Hand-held gimbal	DJI Osmo Mobile 5 gimbal – 3 axis gyro stabiliser
Light	Mobile LED light – 800Lux/0.5m
Supporter	Expansion steel mount

Table 3. List of accessories to the main capture device

4.4.2 Preparation

4.4.2.1 Process Familiarisation

Similar to the first phase (see section 4.3.2.1), I had to familiarise myself with the process of hybrid scanning through experiments and practice. Each scanning principle has its own preferable scanning subject and conditions according to its advantages, disadvantages, and characteristics. The main task was to scan geometry data, such as outdoor places and buildings, to confirm the resulting data's accuracy and the baked texture's stability.

At first, I ran experiments with the mobile LiDAR scanner (MLS) of the iPhone 13 Pro. I tried various applications for the MLS such as *Scaniverse*, *Metascan*, and *Polycam*. While exploring the features and usability, I also tested the reconstruction capabilities on various subjects of different sizes, textures and in different environments. Experimental targets included open outdoor spaces, a palace, part of the river, and stepping stones (see Figure 56 and Figure 57). In addition, point cloud generation (.PLY files) using *SiteScape* was also

performed to experiment with cloud point data (see Figure 58).

Table 4 below lists prices, device compatibility, output format types, and features of each application.





Application	 <i>Scaniverse</i>	 <i>Metascan</i>	 <i>Polycam</i>	 <i>SiteScape</i>
Scan Type	Mesh scan	Mesh scan	Mesh scan	Point cloud
Pricing	Free	Monthly subscription	Monthly subscription	Free
Scan mode	LiDAR/ Photogrammetry	LiDAR/ Photogrammetry	LiDAR/ Photogrammetry	LiDAR
Output Formats	Mesh: USDZ, FBX, OBJ, GLTF, STL Point Cloud: PLY, LAS	Mesh: USDZ, FBX, OBJ, GLTF, STL Point Cloud: PLY, LAS, XYZ	Mesh: USDZ, OBJ, GLB, DAE, STL Point Cloud: DXF, PLY, XYZ, PTS, LAS	Point Cloud: PLY, e57
Operating System	iOS	iOS	iOS/Android	iOS
Features	No LiDAR mode. Capable of scanning small-scale objects (< 10cm) in detail mode	Provides switching viewpoint to aerial point of view. Maximum of 300 photos	Includes room planning, object scanning mode, providing cross-to-web scanning	Architectural scanning compatible

Table 4. Comparison of Mobile LiDAR application features



Figure 56. Experiment with *Scaniverse*. Objects were chosen to test scanning area limits of the application (left), the ability to scan fluid substances such as water under a bridge (center), and the ability to reconstruct complex architectural structures, such as Korean palaces (right).

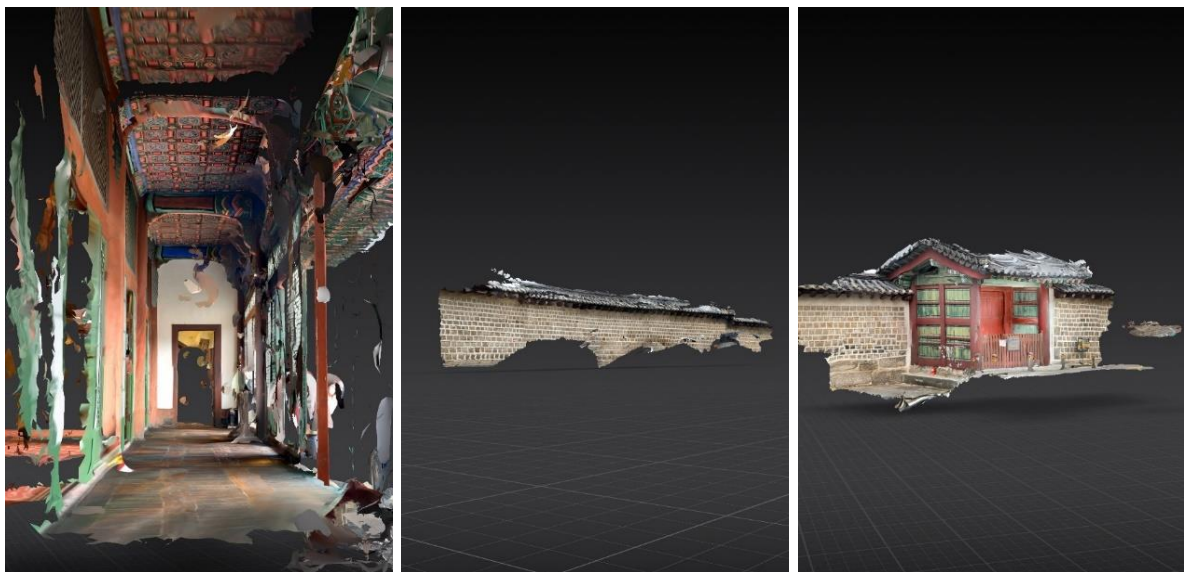


Figure 57. Experiments with *Metascan*. The application was tested by scanning in locations with limited access and insufficient lighting and creating textures for natural-material-based architecture by scanning the brick walls of Korean palaces. I also tested the potential for scanning the complex structure of traditional Korean architecture.

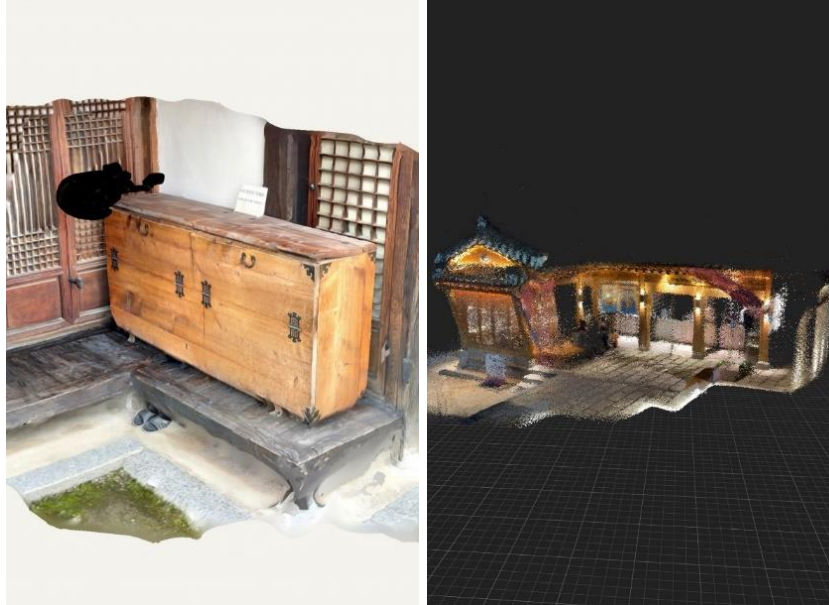


Figure 58. Experiments with *Polycam* and *SiteScape*. Simple tests were conducted with the respective applications, including object scanning of traditional furniture using *Polycam* and point cloud scanning using *SiteScape*.

Next, I experimented with videogrammetry. Despite the similarities to the principle of photogrammetry, I needed to gather experience with differences in the data acquisition method such as finding the optimal distance from the target and the movement path for the camera. This exercise was conducted in *Changdeokgung* palace, which has a unique construction style and various colours as decoration on walls. These architectural features can help align each position of the images in the creation of the mesh and help verify the accuracy of the texture among the generated results.

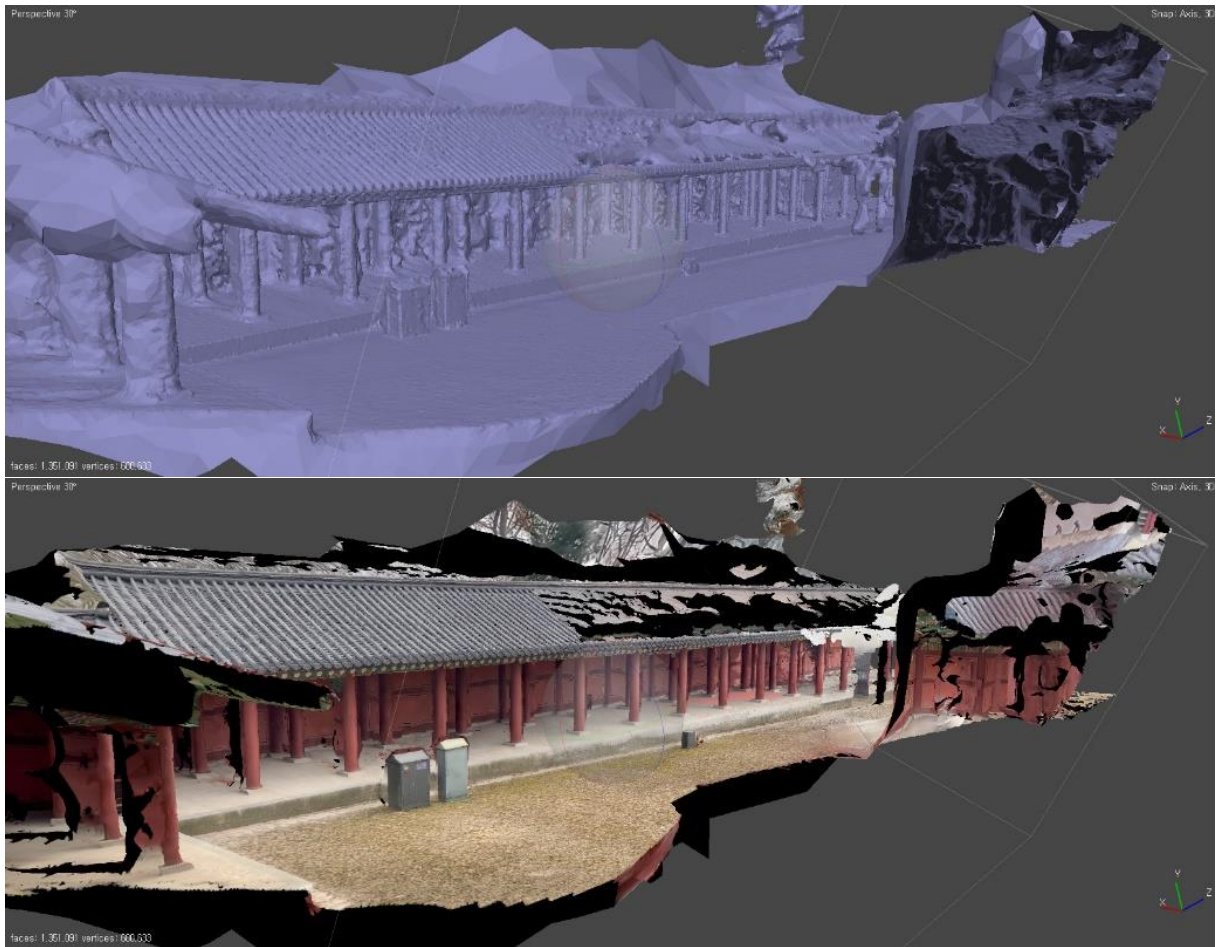


Figure 59. Experiments with videogrammetry of a corridor in *Changdeokgung* palace

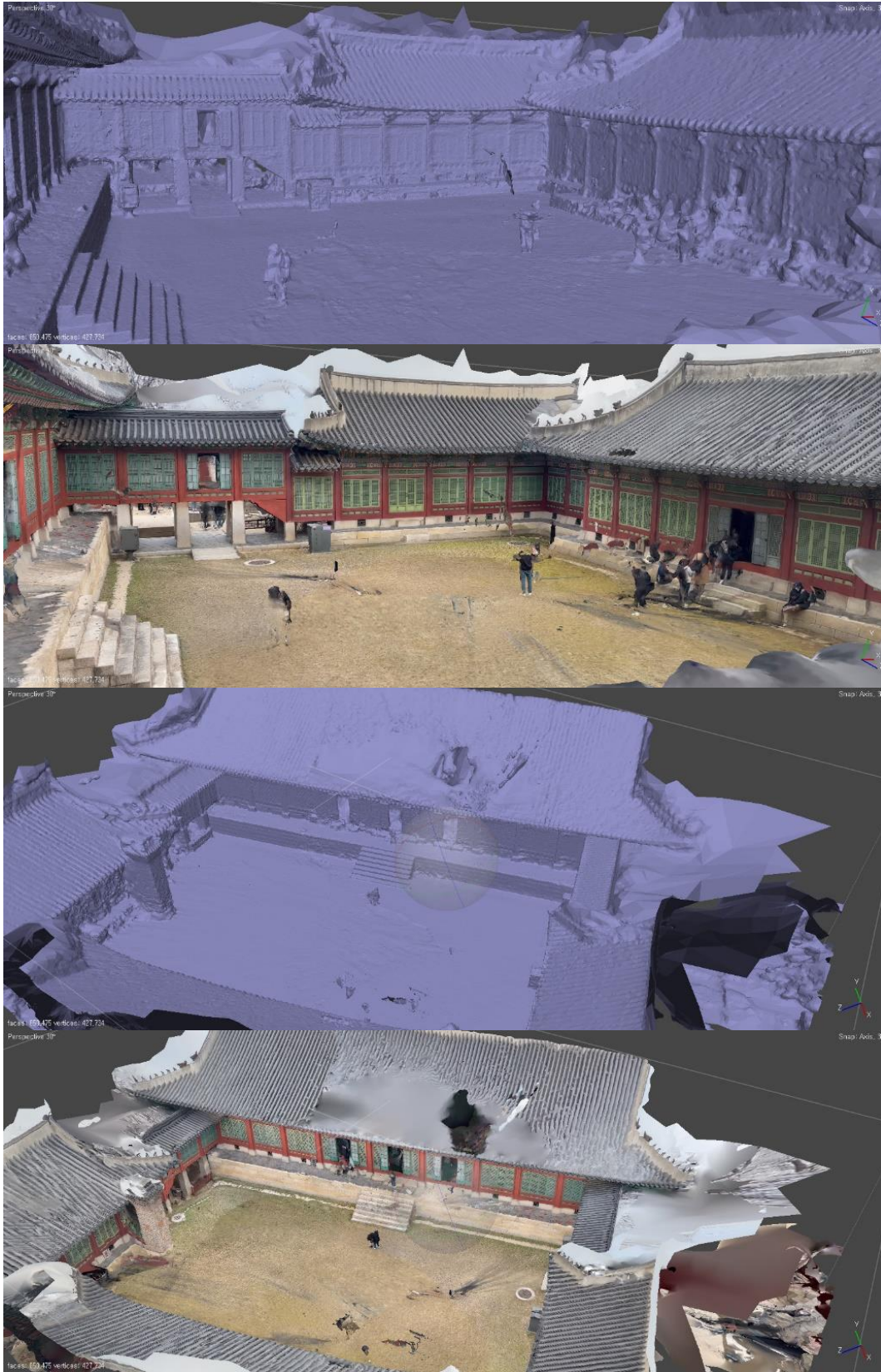


Figure 60. Experiments with videogrammetry of a yard in *Changdeokgung* palace

The experimental area was limited to two places where a specific environment could be tested in the area of the palace. The first was an outdoor corridor consisting of many pillars that required a long filming distance (see Figure 59). The recording duration was 2m:48s, and the amount of images used for reconstruction was 317. The second area was an outdoor garden surrounded by buildings (see Figure 60). The recording time for this target was 5m:30s, and the final number of aligned images was 561.

During the analysis of scanning data, I realised that the recording path affects the results of data acquisition via videogrammetry quite significantly. Especially during the experiment in the palace yard, my capture path (see Figure 61) was incomplete due to some areas being obstructed by other visitors. Due to this, I lost data, and those missing images in certain angles caused holes and lack of texture on some mesh surfaces (see Figure 62).

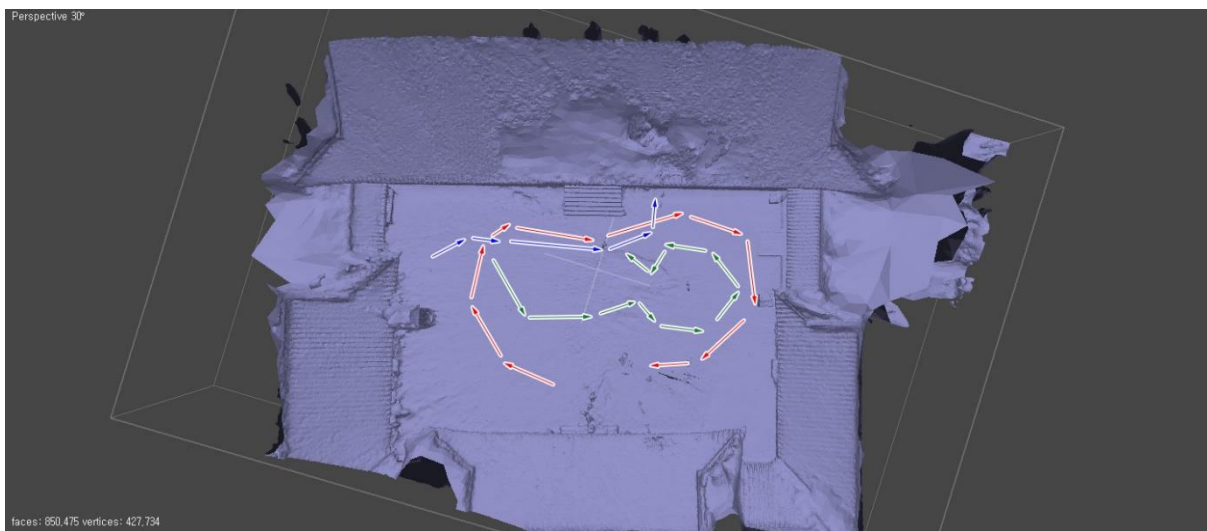


Figure 61. Recording path of the palace yard

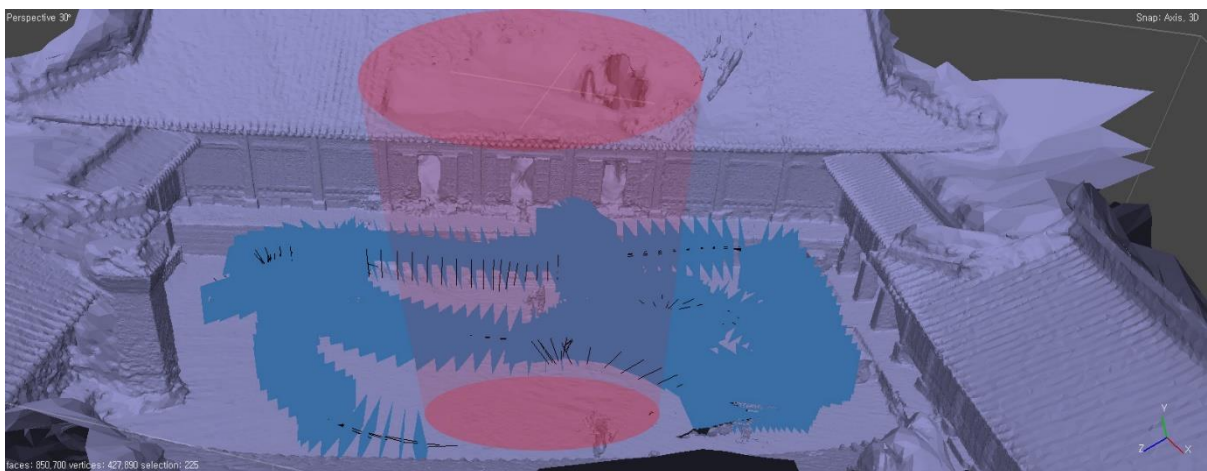


Figure 62. Missing mesh data caused by lost footage due to obstructions and an incomplete recording path

As a last experiment, I scanned one side of the surface in the yard using both methods to compare MLS and videogrammetry. MLS data (see Figure 63) shows higher accuracy in generating structure due to its data scanning process that allows for real-time quality control on the mobile phone. However, it was impossible to supplement the missing data during filming because it had to rely on its own functions provided by MLS. On the other hand, videogrammetry data (see Figure 64) shows a wider coverage and a high-detail texture reproduction on a specific surface but fails to show a uniform quality spatial composition. I remembered that this was a disadvantage I had identified in the first phase because the completeness of the data acquisition depends on the user's proficiency and predictability of implementation.

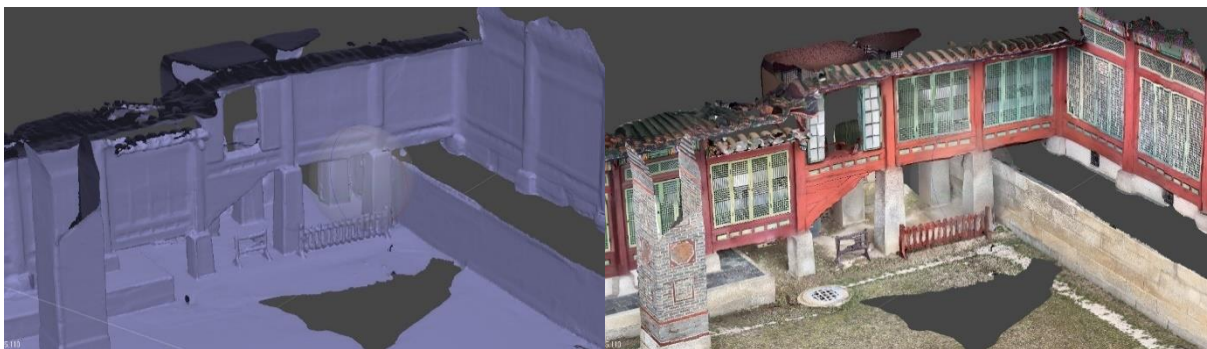


Figure 63. Scanning results of MLS

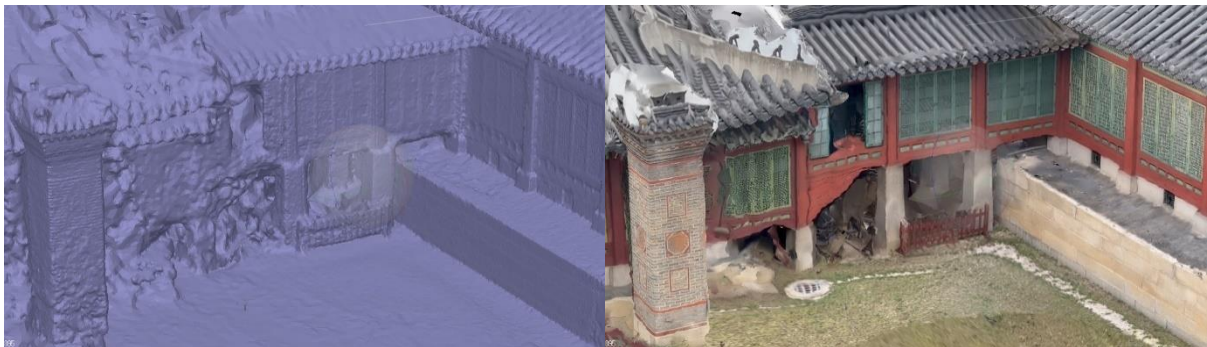


Figure 64. Scanning results of videogrammetry

4.4.3 Acquisition (27–29 March 2022)



Figure 65. Different weather conditions between the first and second acquisition phase. Overcast weather in December 2019 (left) and sunny weather in March 2022 (right)

On my second visit to the target site, the conditions were very different from my first journey. The first factor that had changed was the weather on the set (see Figure 65). Unlike the even and diffuse characteristics caused by the overcast sky in the first phase, this time, the subject had strong shadows due to the harsh sunlight. The weather condition affects texture baking, but my acquisition schedule was not adjustable, so I decided to add a texture de-lighting step into the processing workflow. The second factor was a change in the management policy of the heritage site, which now allowed me to enter the interior areas of the *Choga*. This policy change resulted in a much smoother MLS data collection.

Videogrammetry was used as the main capture method. For the recording, I moved in a spiral direction from the outside of the site's stone wall to the inner yard to scan the entire *Choga* site structure while making sure to capture each house's outer walls (see Figure 66). This videogrammetry recording path requires similar considerations and planning as it would to determine the positions from where to take the series of photos for photogrammetry. The recording was done in one continuous 10m:56s video clip. Unlike in the 2019 field trip, this recording time is reasonable and avoids changes to the environment, such as weather and sunlight. The way to import video resources into *Metashape* is configurable and provides automatic extraction of individual frames, in this case one image every 30 frames (see Figure 67). From there on, the alignment process is identical to photogrammetry. Through this import process, a total of 626 images were extracted, and 624 available images were used for image alignment in *Metashape*.

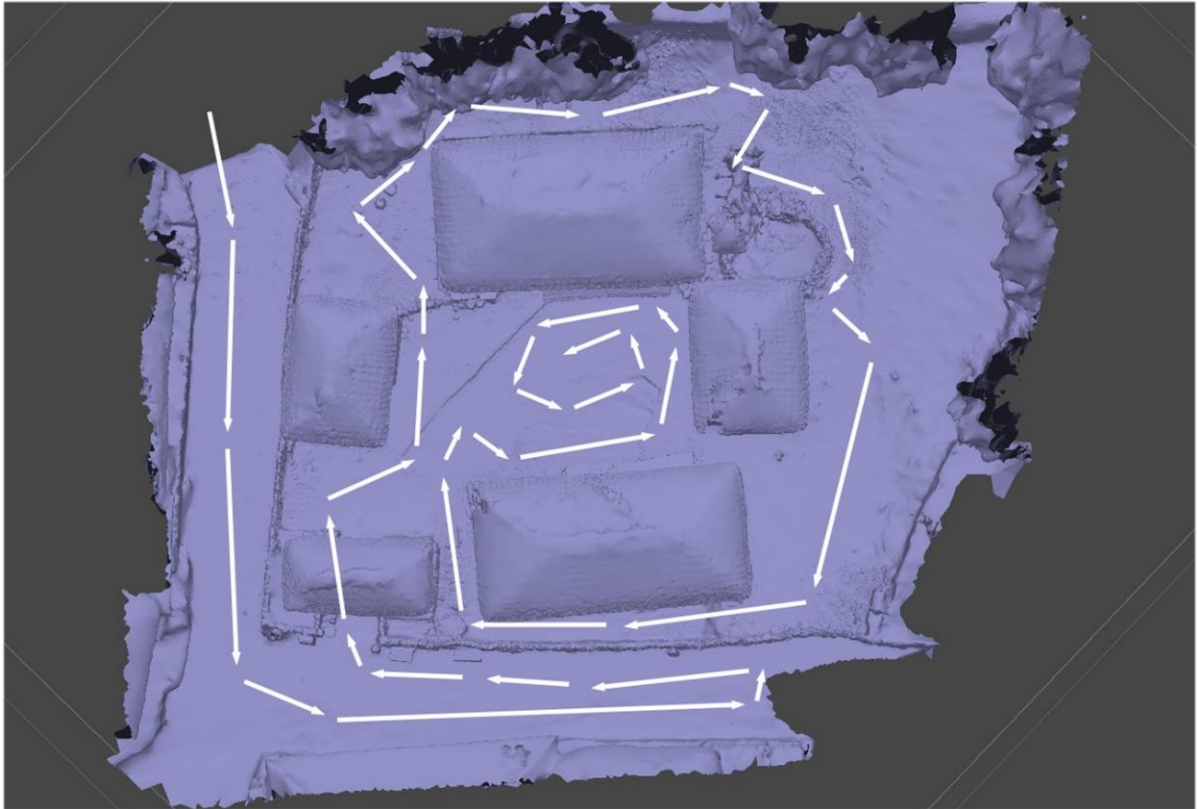


Figure 66. Videogrammetry recording path of the *Choga* site

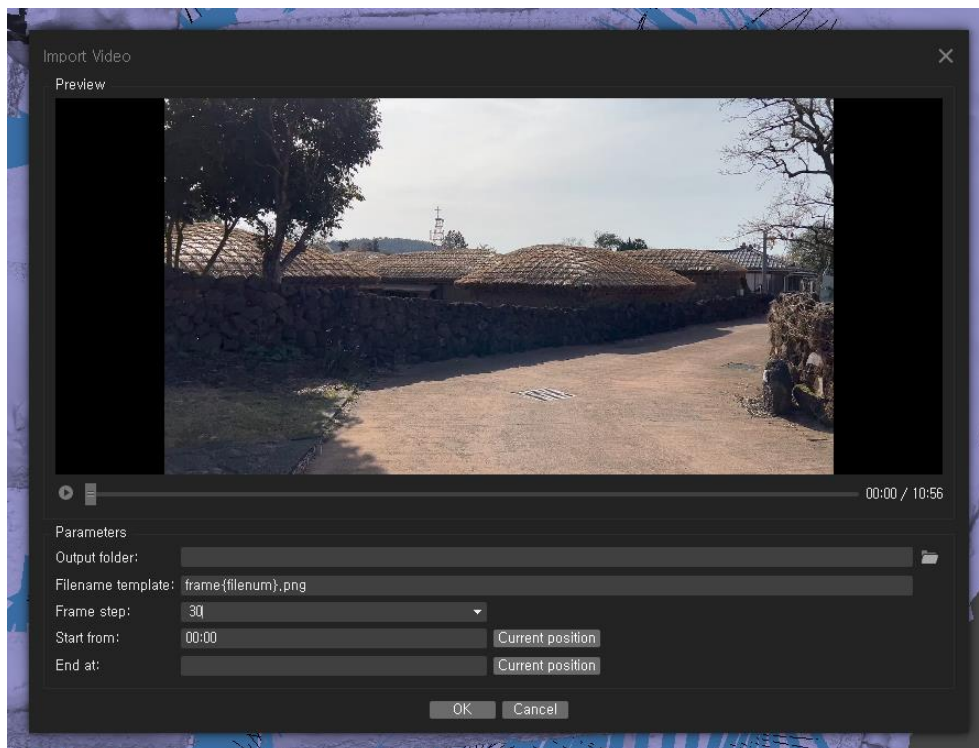


Figure 67. Video frame extraction setting in *Metashape*

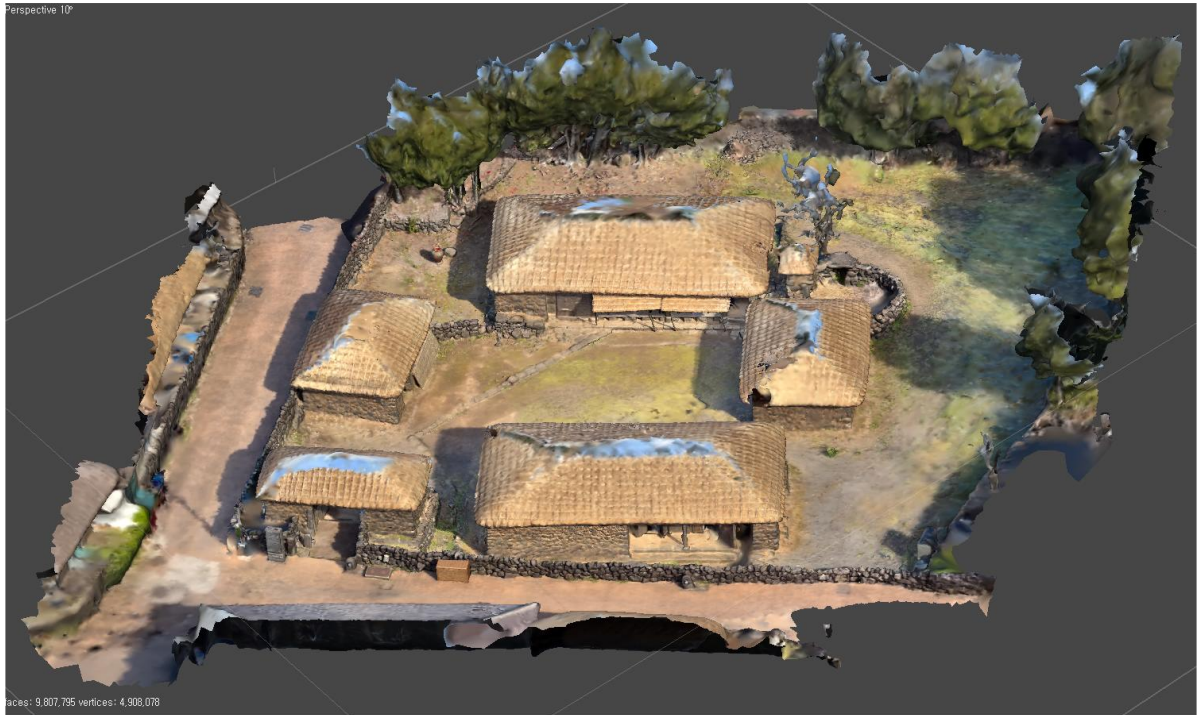


Figure 68. Generated data from videogrammetry. Certain surfaces of the roofs are missing, indicated by the blue areas that have been replaced by the sky.

Although the appearance of the model generated through videogrammetry looked good overall, and no serious omission was observed, data loss occurred in certain areas of each house, such as the main house's entrance and the sub house's rear (see Figure 69). For this reason, specific areas were planned in advance (see Figure 70) to be captured via MLS (workflow shown in Figure 71) to prevent the likely incomplete data acquisition caused by lack of indoor light. Some results of these MLS scans are shown in Figure 72.



Figure 69. Comparison between videogrammetry (top) and MLS (bottom) results. Videogrammetry shows a realistic look of the textured mesh (left), but the solid view mode (right) makes insufficient mesh generation apparent. In contrast, the MLS result shows a more detailed mesh and overall higher accuracy of the structures.

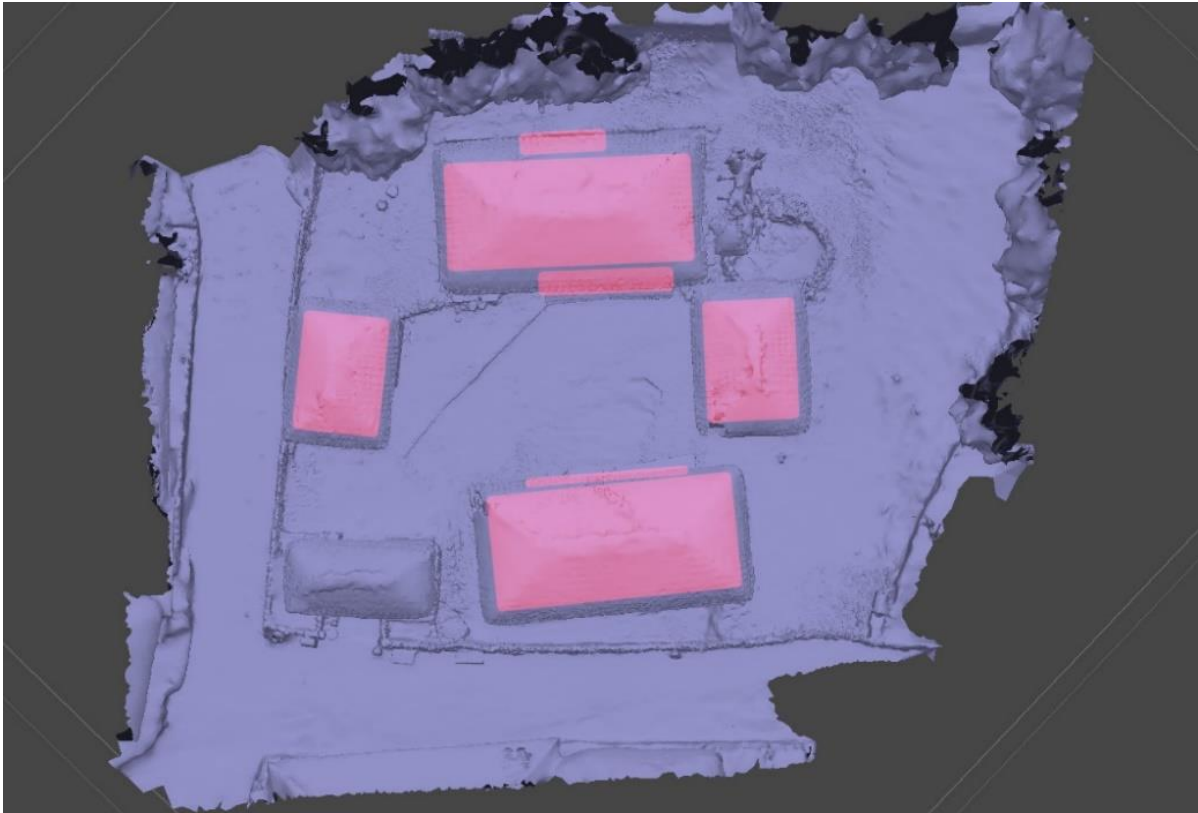


Figure 70. Selected areas to be captured by MLS

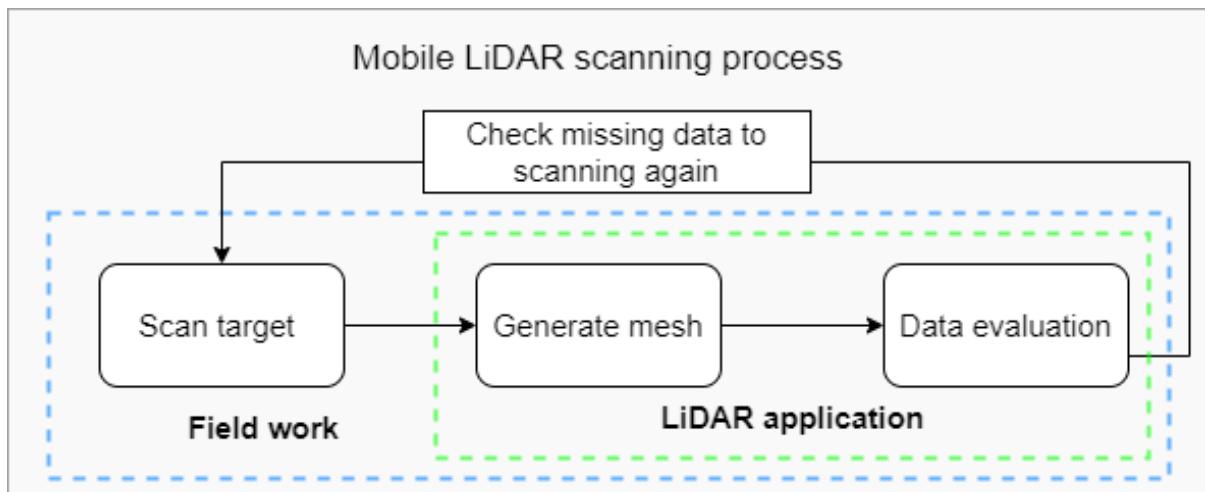


Figure 71. Workflow for MLS

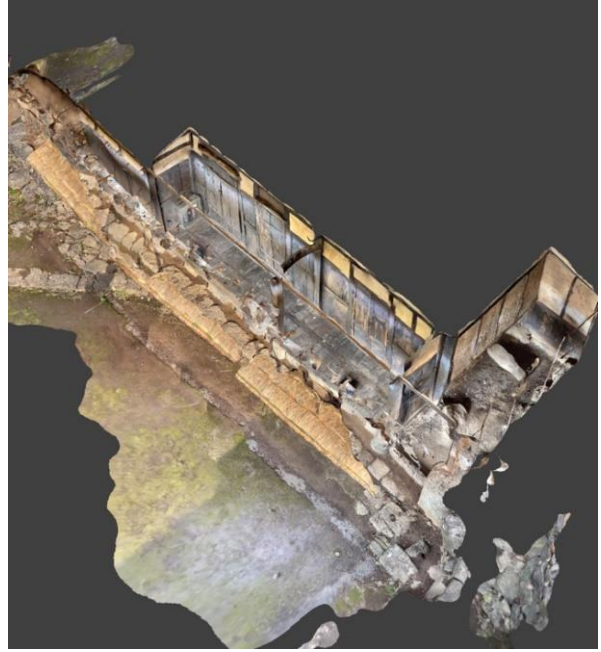


Figure 72. Examples of generated data from MLS. Top left: main house kitchen, top right: main house front area, bottom left: inner space of main house include missing data from first acquisition trip, bottom right: complete inner space of sub house.

4.4.4 Data Processing Workflow

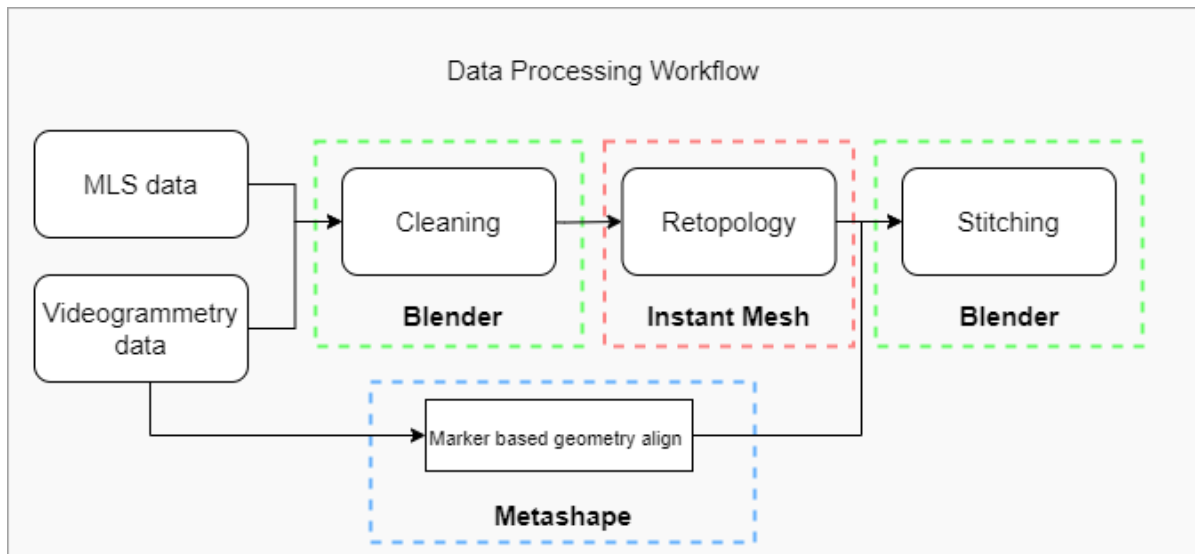


Figure 73. Data processing workflow for videogrammetry and MLS

There were three steps to modify the data processing workflow for handling the data from videogrammetry and MLS (see Figure 73): Mesh cleaning, retopologising, and stitching. The cleaning step was mainly carried out using *Blender's* mesh sculpting function. Retopology used the polygon count reduction function of *Instant Mesh*. Finally, each dataset was integrated with geometry information by synchronising LRS information of MLS data based on videogrammetry data, using the chunk alignment function provided by *Metashape* before the stitching process (a chunk representing a generated geometry grouped by a certain set of images).

4.4.4.1 Restoration and Cleaning up

After generating high-resolution (Hi-Res) models in *Metashape*, some of the scanned models had lost structure and detail and had holes in the mesh (see Figure 74).

Incomplete mesh generation was also observed during the workflow of the first phase (see Section 4.3.3.2), but unlike the previous workflow where I did retopology first before clean-up, in this phase, I executed restoration of the data first. Exported models from *Metashape* were imported to *Blender* to use its sculpting mode to edit the High-Res mesh models (see Figure 75).

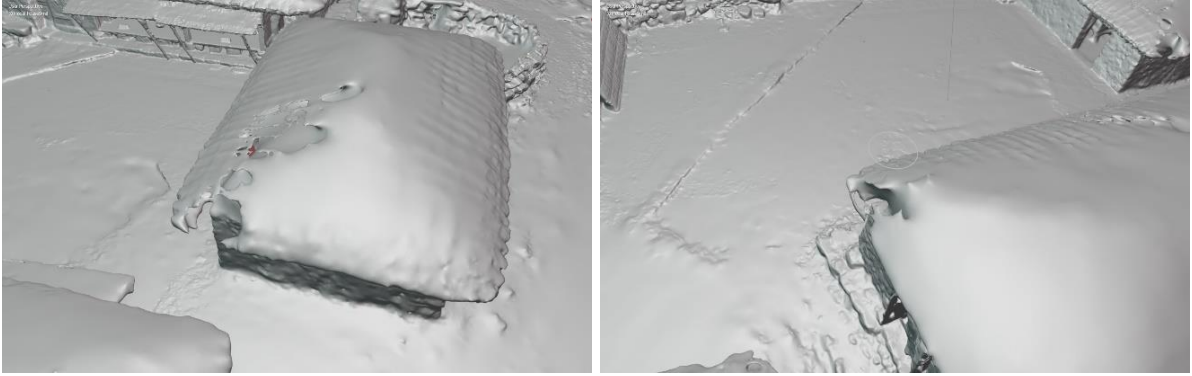


Figure 74. Incomplete surfaces on the Hi-Res models

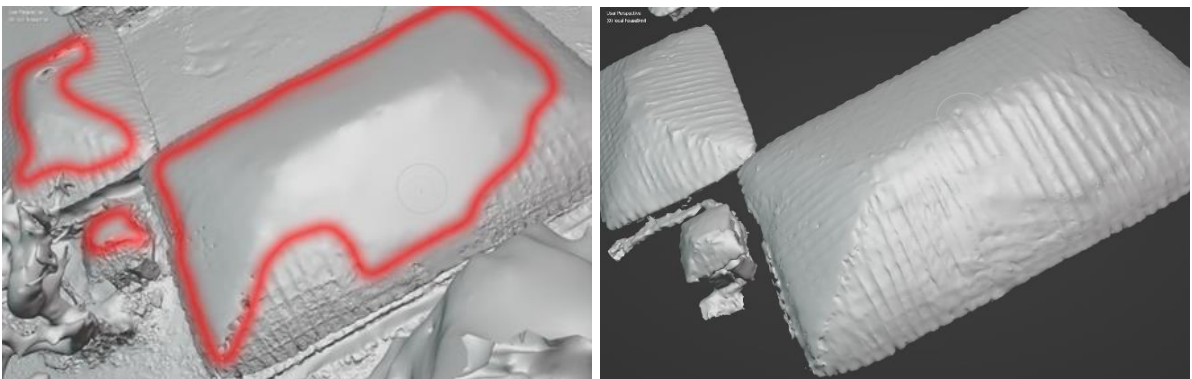


Figure 75. Lost detail and holes on the surfaces (left, red lines) and the result of restoring the surface with detail and filling in holes (right)

During the sculpting process, I also supplemented missing data with some redesigned meshes (see light gray areas in Figure 76) based on the shape and formation patterns of the adjacent surrounding data.

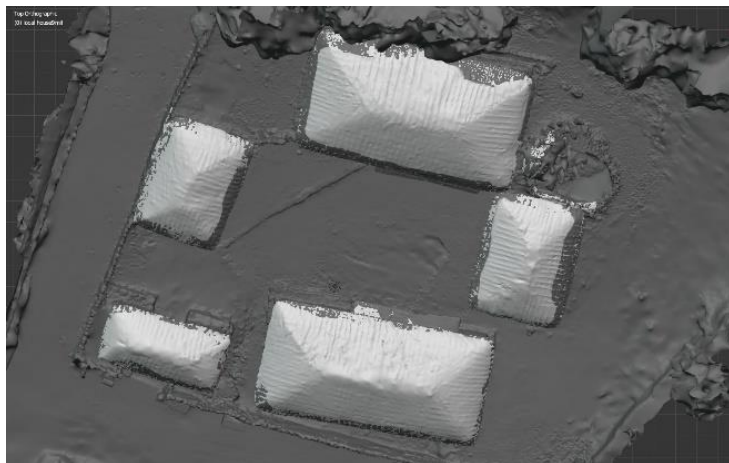


Figure 76. Sculpted mesh areas (light grey) to restore lost details of the roof areas

4.4.4.2 Retopology

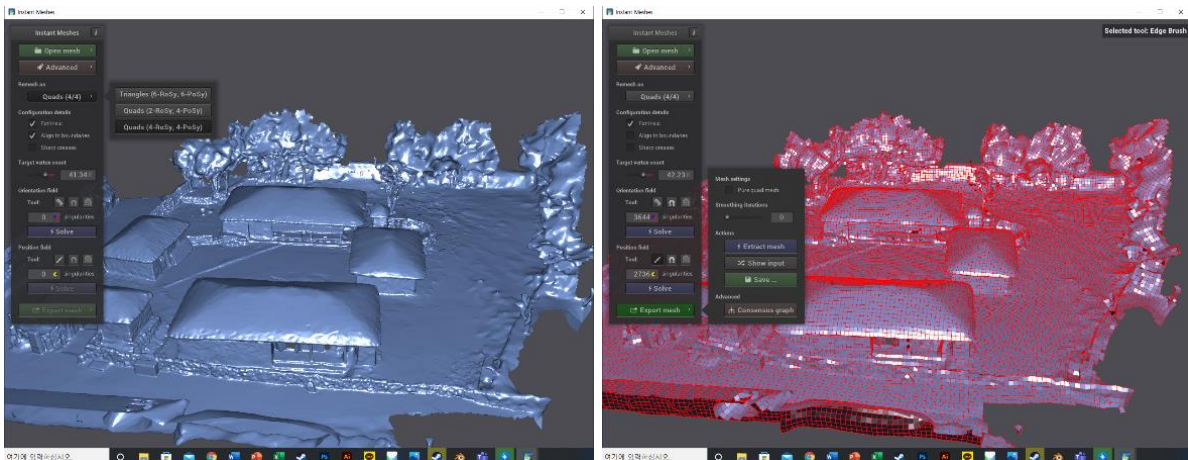


Figure 77. Applying retopology to reduce the polygon count from 9,807,795 (left) to 262,498 (right)

Cleaned videogrammetry and MLS mesh data were retopologised in *Instant Mesh* (see Figure 77), resulting in a reduction of the polygon count from almost 10 million to 262,498. However, during this process, certain MLS data showed conversion issues (see Figure 78) caused by specific formation processes of the mobile LiDAR applications. In the export process of *Scaniverse* to OBJ format, the generated texture UV coordinates were corrupted. I contacted the developer team of *Scaniverse* about this issue, and it was solved with a patch that fixed UV coordinate generation for certain export formats.

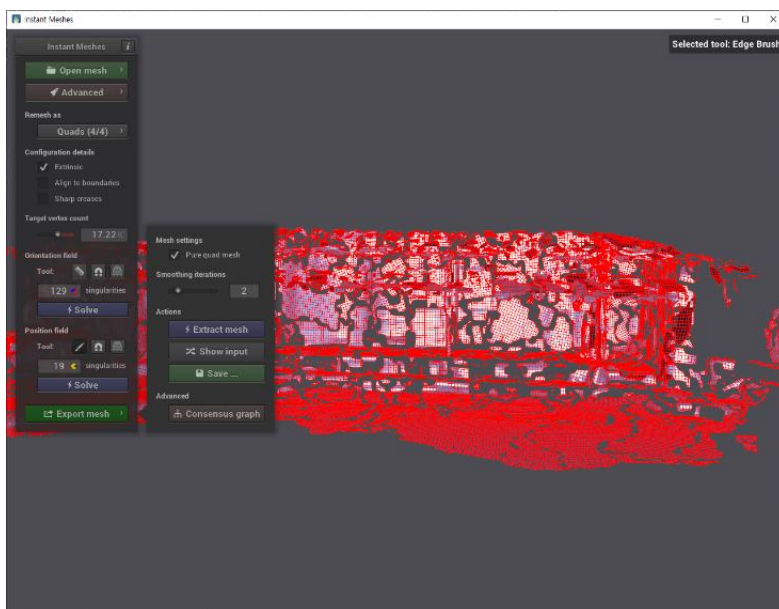


Figure 78. Reproducing an issue that separated surface UV coordinates from MLS data

4.4.4.3 Stitching



Figure 79. Compatible matching points for aligning geometry data between videogrammetry (left) and MLS (right) output

During the stitching process, the mesh models need to be synchronised according to each other's geometrical information. Therefore, I imported models into *Metashape* to use the “align chunk” function for matching geometry. *Metashape* runs with the concept of a “multiple chunk project” in which each chunk comprises of a dataset of images and the resulting geometry information (Agisoft Metashape, 2021). Among the align chunk functions, marker alignment can associate markers with geometry points, e.g., specific colour points on surfaces or arrangements of components like stones (see Figure 79 and Figure 80) that match each generated chunk and compare them to align them by translating, rotating and sizing the model accordingly.

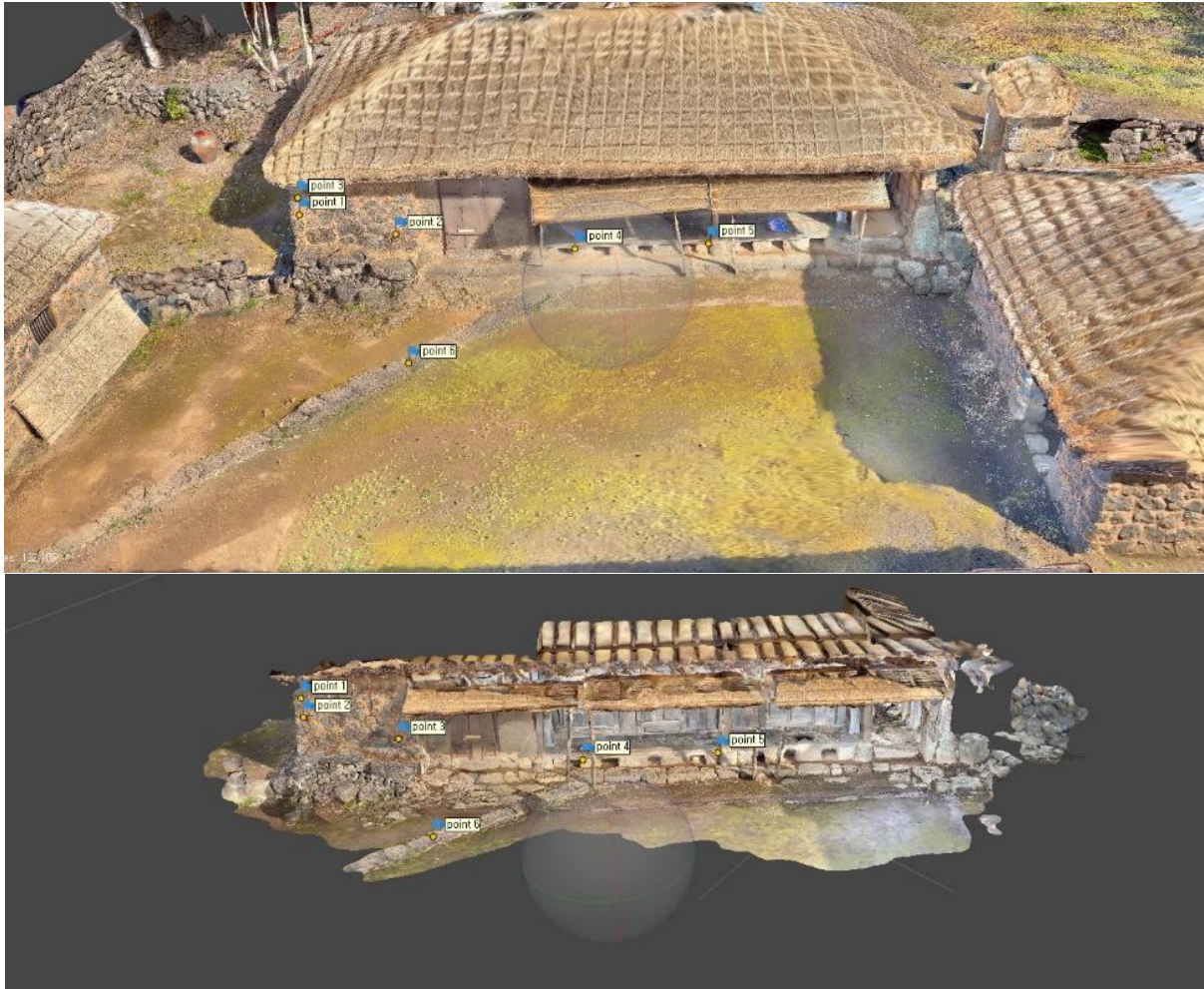


Figure 80. Example of marker positions for chunk alignment of videogrammetry (top) and MLS (bottom) meshes. Each point has enough distance from any other point to result in a clear alignment transformation. Seven markers were used to align chunks for stitching the main house's front part.

The alignment process automatically proceeded based on a geometrical comparison of markers (see Figure 81). I then exported the aligned model as OBJ format with the adjusted geometry information and imported it back into *Blender* to edit the overlapped meshes of each model. This was done using a Boolean modifier, which performs intersecting or differencing meshes (Blender, n.d.), together with a cube object to cut out overlapping meshes (see Figure 82).

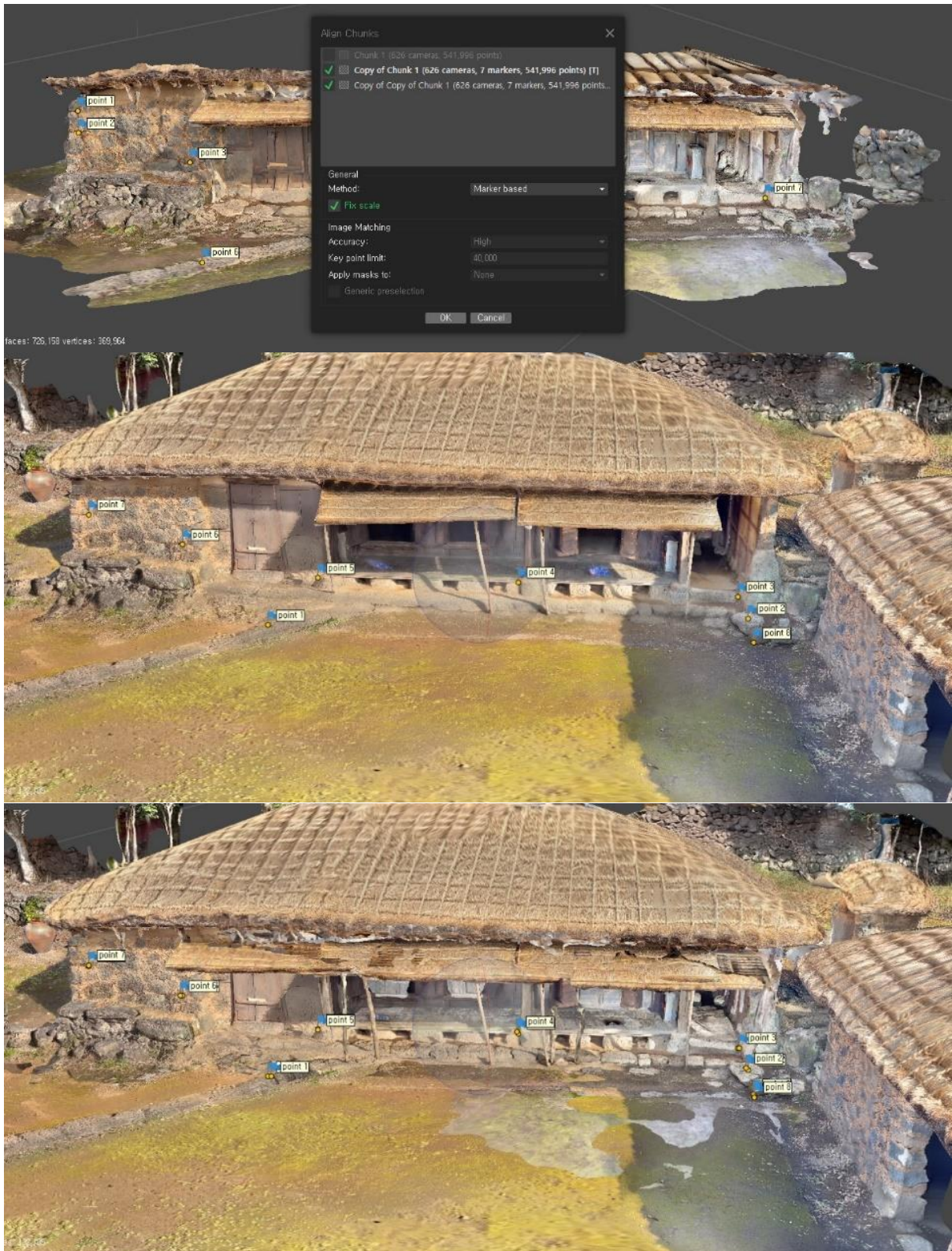


Figure 81. Stages of the automatic process of chunk alignment.

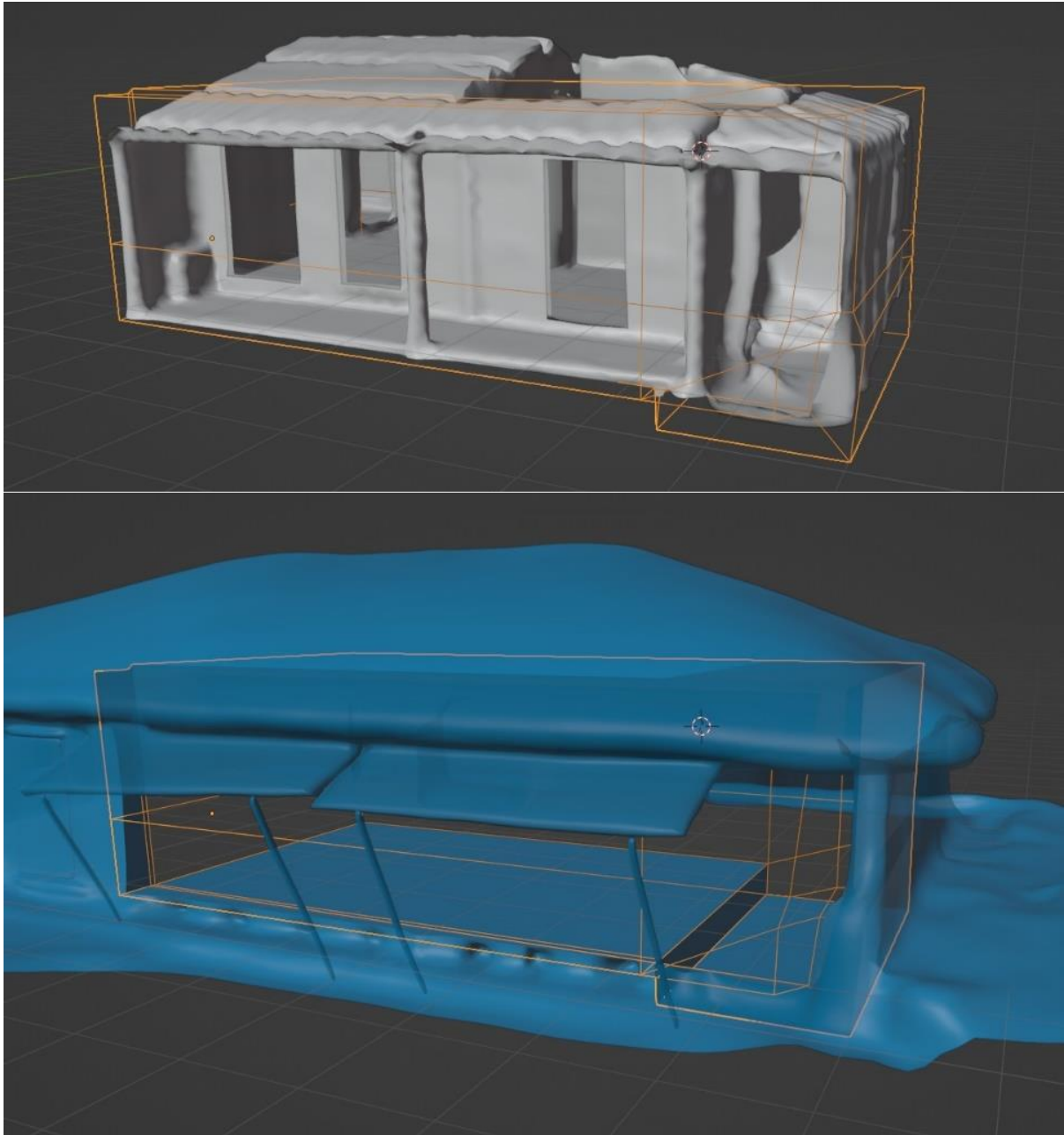


Figure 82. Cutting out models using a Boolean modifier with cube shapes. MLS data (top) was isolated in intersection mode, and videogrammetry data (bottom) was cut in difference mode.

4.5 Game Engine Workflow

If this project were to only focus on the exact digital reproduction of cultural heritage, a high resolution model would be preferable and the retopology step for reducing the polycount would not be recommended. However, to produce a serious game and give the user an enjoyable play experience, additional processes are needed to optimise the content for the game engine. This section explains the two extra workflow steps that were implemented before importing the 3D data as game components from a level design perspective: Texture editing and Splitting the large-scale model.

4.5.1 Texture Editing

From the mesh-generating process in the photogrammetry software, the image texture is normally included as a result of processing. However, even in the default process with a simplified model generated through data organisation (discussed in Section 4.3), the texture layout showed ununified texturing on the model's surface (see Figure 83 and Figure 84). It is challenging to clean up this unmodified texture with image editing software, and it can also cause problems when importing large-scale models into a game engine for VR. Markovic (2018) demonstrated how to generate an improved UV map for covering the low-polygon model from the complex scan data of a large ship named "Edwin Fox". In her thesis, Markovic explains that "clean UVs" are widely used in digital content for covering the low-res model, which has a large surface, and this UV cleaning process is required to export the retopologised model for the game engine. Various modelling software supports a UV unwrapping function. In this stage, *Blender* was used with *UV Pack Master3* (UVPackmaster Documentation, n.d.), an add-on for generating UV maps with UDIM layout.

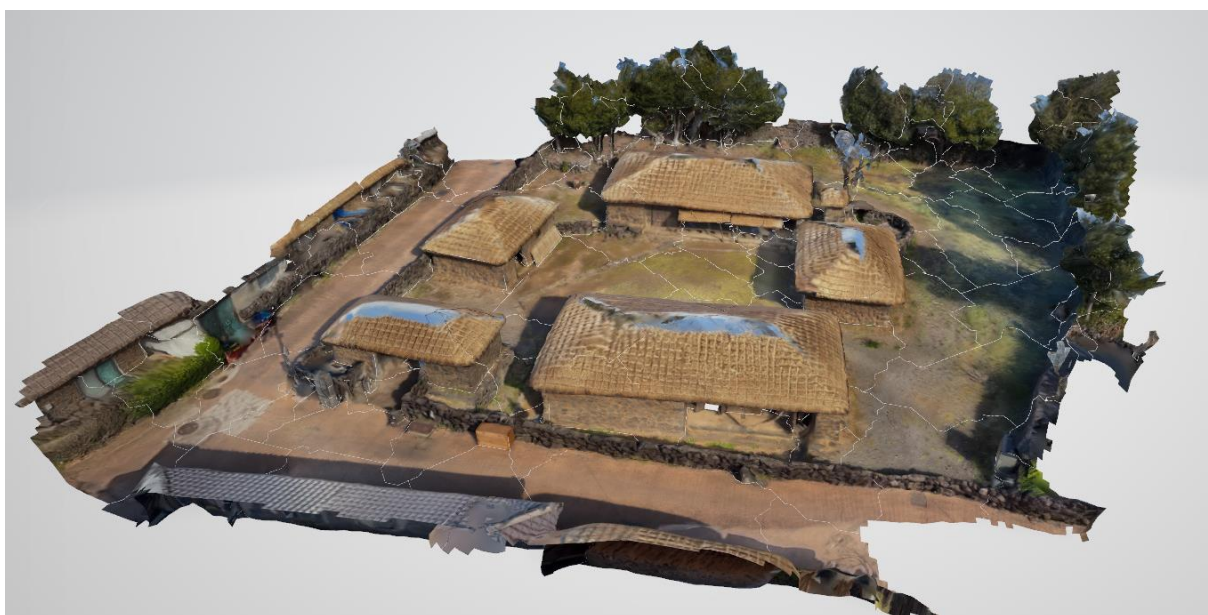


Figure 83. Generated UV map and texture on a simplified model in *Metashape*. The thin white lines indicates borders of each UV group or “island”



Figure 84. Auto-generated, unoptimised UV layout in *Metashape*.

In Figure 85, red lines represent “seams”, indicators to assist the slicing process of meshes for dividing it into optimised UV “islands”, clearly distinguishing separate areas (Bot et al., 2019). In this stage, I manually separated the 3D model into optimised parts by marking seam edges in *Blender*. After this step, the formation of UV islands in the UV layout was generated by UV unwrapping (see Figure 86). This UV layout was generated on one texture map and exported with the model as OBJ format. I then imported this file into *Metashape* to build textures based on the edited UV layout.

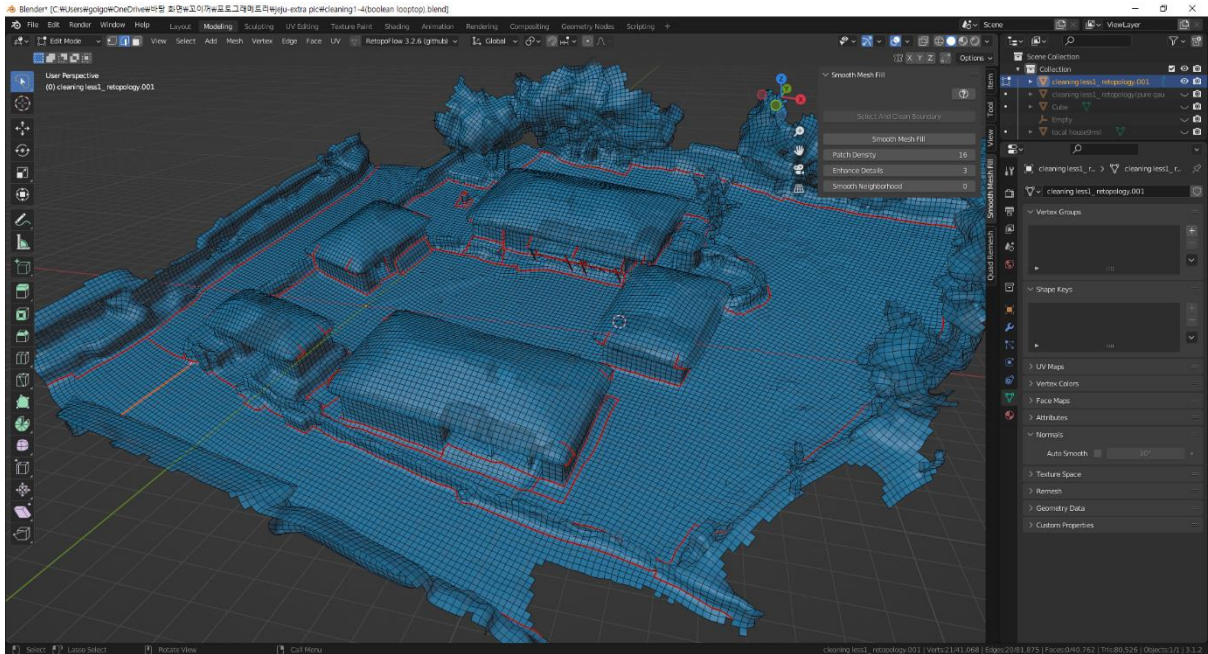


Figure 85. Marking seams for optimised UV unwrapping in *Blender*

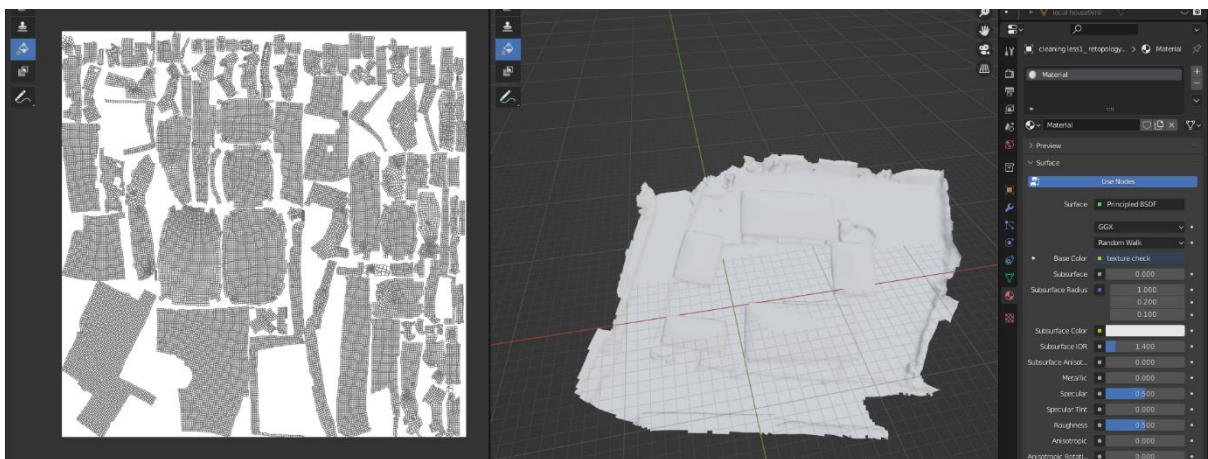


Figure 86. Unwrapped and optimised UV layout in one texture image

Metashape's texture-building process allows the selection of mapping modes (Figure 87) to vary depending on the presence or absence of UV data in the imported model. Since the *Choga* model already has UV islands edited from *Blender*, the texture was re-baked using the corresponding UV layout. Through the baking process, the diffuse texture data (see Figure 88) of the house's site looked good without distortion and missing surfaces.

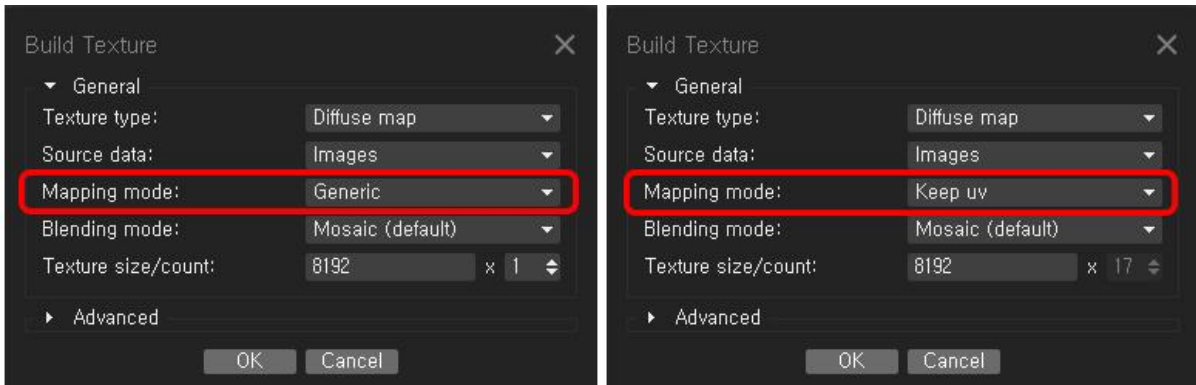


Figure 87. Different texture mapping mode options in *Metashape*

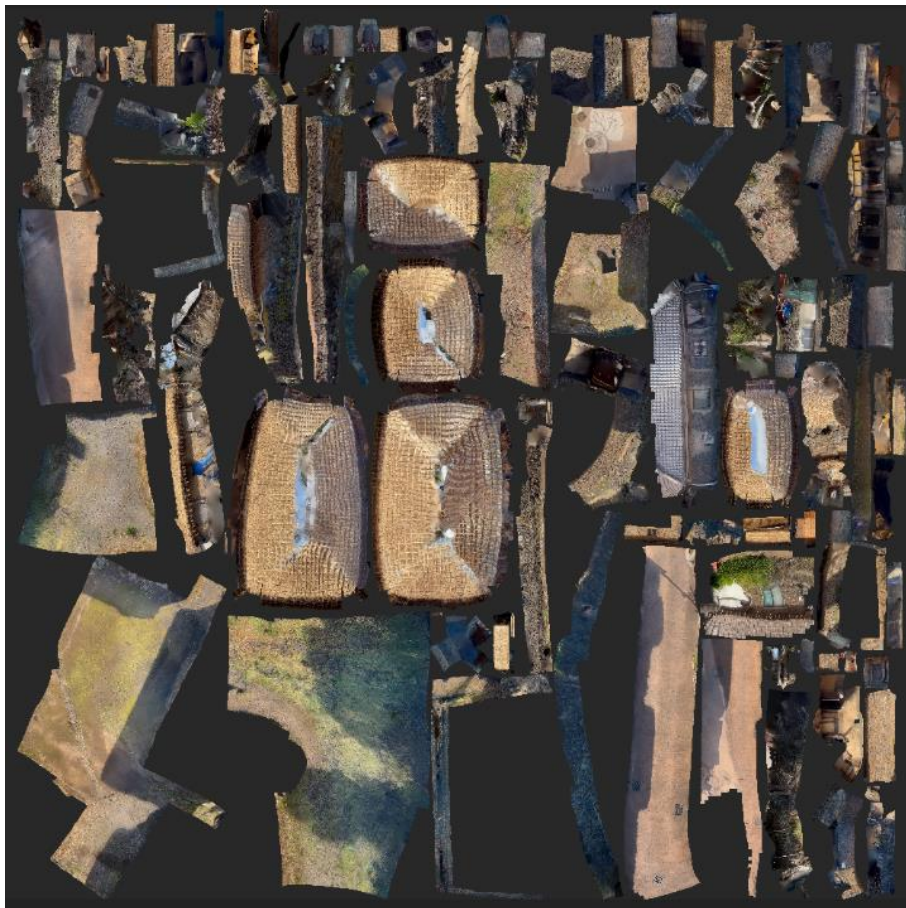


Figure 88. Baked diffuse map in *Metashape*

Because of the harsh sunlight conditions encountered in the second acquisition phase, I also attempted to apply a de-lighting process to reduce the harsh contrasts on the textures. As software, I used an artificial intelligence feature in the software *Substance Painter*, but the process was not effective enough to result in a significant improvement.

4.5.2 Splitting the Model

After the texture baking process, since it is necessary to maintain a high resolution of the textures, the available texture space was allocated and distributed for each area of the *Choga* model. This work utilised the UDIM layout creation function of Blender, but it was used only as a criterion for dividing the texture, because *Unity*, the game engine to finally import the data into, does not support the UDIM function.



Figure 89. Dividing the texture map into a UDIM layout in *Blender*



Figure 90. List of separated pieces from *Choga* data

Choga's geometry was divided into a total of nine areas: four areas for the main buildings such as the main house, the sub house, the gate, and the storage and stall; five areas for the rock fence surrounding the site, the toilet, the inner yard, the outside road, and the surrounding environment. I sorted the textures of each area in one texture layout to facilitate subsequent post-processing.

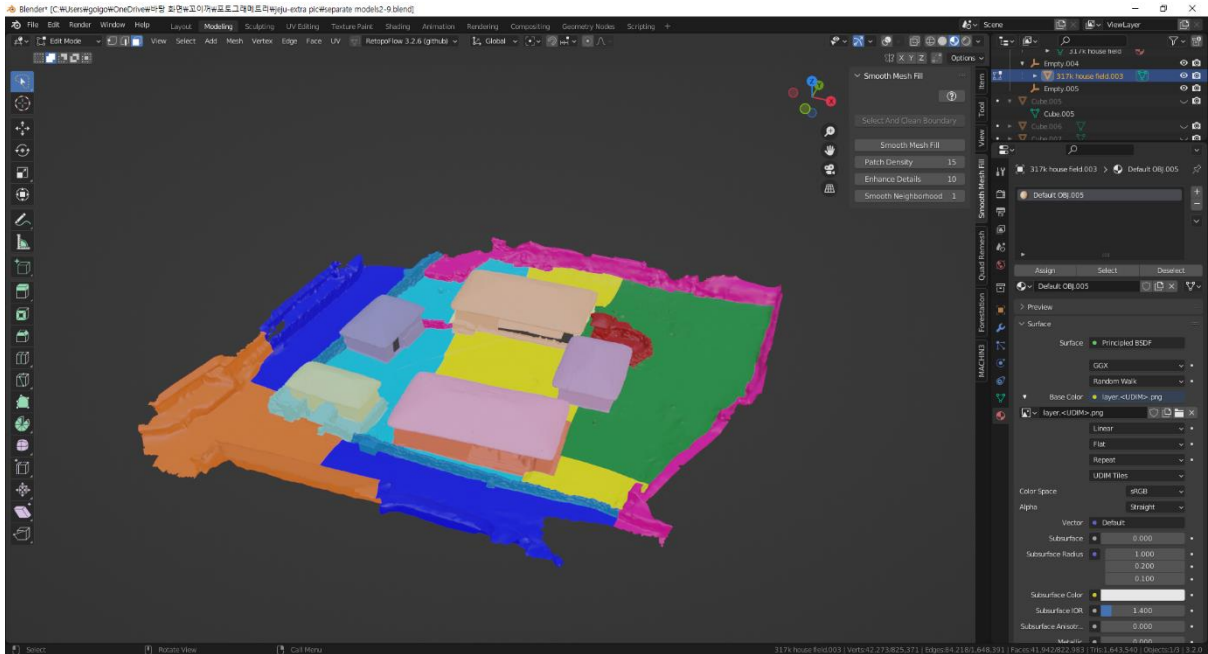


Figure 91. Separating areas of the *Choga* model in *Blender*

In addition to the segmentation of the texture, the 3D *Choga* mesh data were also divided according to the segmentation of the UV layout. This is because a large number of polygons over a large area in the game engine can affect performance. By dividing the model up, one of the optimisation methods of the game engine, object culling, can more easily ignore parts that are not in the current user's field of view.

4.6 Development of the Virtual Reality Experience

The resulting processed mesh data was imported into the Unity game engine to create the virtual heritage experience. Due to the two data acquisition phases, this Unity project also went through two versions in 2019 and 2022. The following sections will describe the changes within the two versions.

4.6.1 Changes from 2019 to 2022

During the two reconstruction phases, there were four main changes to the Unity project: First, the changes in the library used to implement VR interactions. In order to build a virtual environment, libraries provided through game engines or other external add-ons or additional applications are required to implement Virtual Reality and provide consistent interactions. I had used SteamVR as the main library for the 2019 version of the virtual environment (see Figure 92). After completing the second data acquisition phase in 2022, the program version of Unity used for my project was changed from 2019.2.6f1 to 2021.3.1f1 due to the new support of the XR Interaction Toolkit, a library I decided to use instead of SteamVR for creating the virtual environment (see Figure 93). With this XR interaction toolkit, the project could be built on multiple platforms, e.g., PC and standalone VR headsets, rather than being only limited to devices that support SteamVR.

The second change was the revision of the interaction and input system as a result of the library change described above. When developing the VR interaction using SteamVR in 2019, I had to painstakingly configure the input system for each VR device individually, and incorporation of other devices from other manufacturers would have been difficult. A lot of manual work is necessary to have interactions such as movement, holding objects, and teleportation to a specific areas behave similar on different devices. In contrast, the XR Interaction Toolkit used in the 2022 version shortened the development process because it can allocate and use a uniform interaction for each controller button of various VR devices without a separate binding process per device.

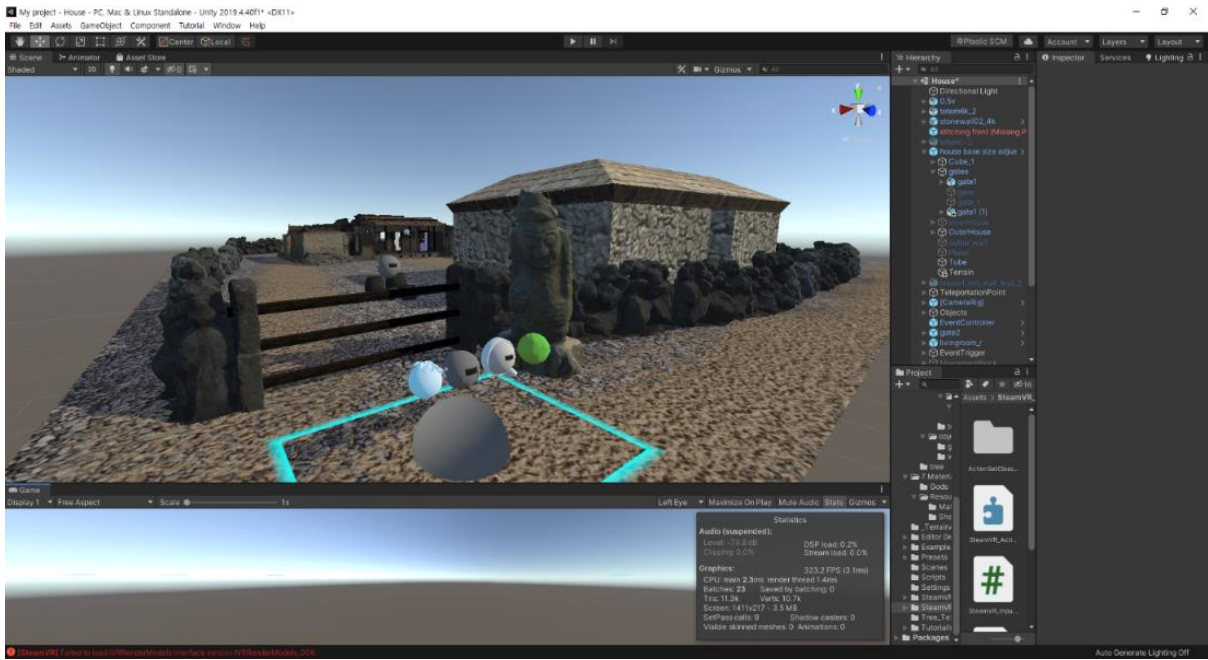


Figure 92. Screenshot of work-in-progress assembled in 2019

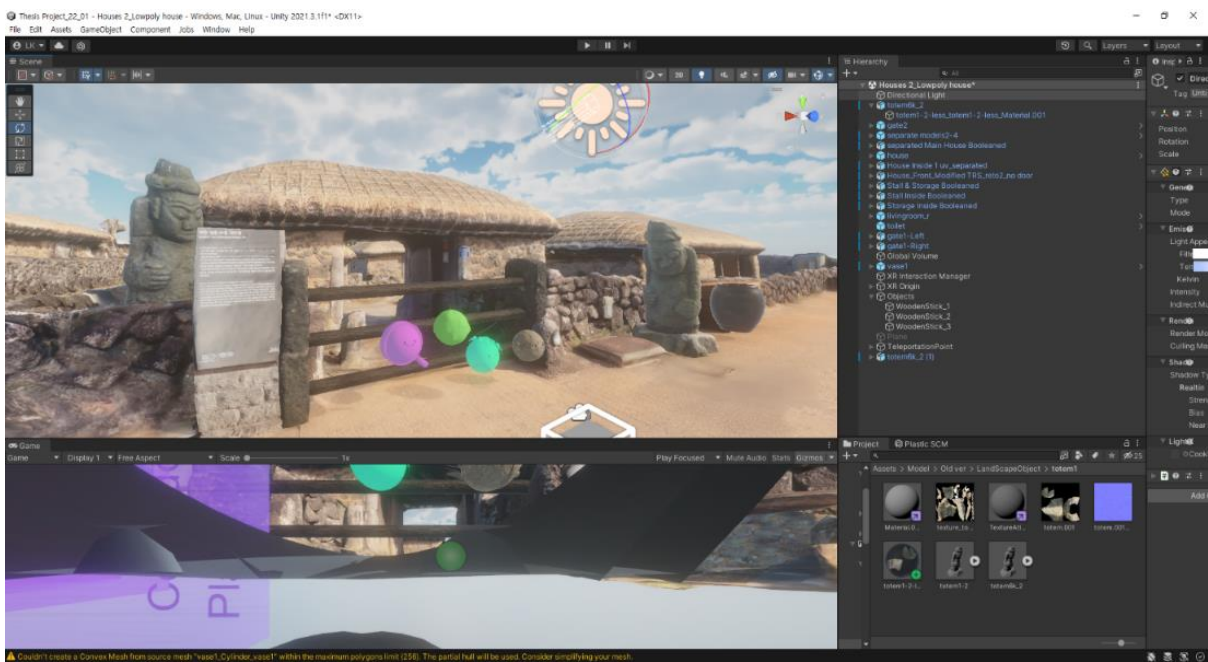


Figure 93. Screenshot of work-in-progress assembled in 2022 (low-res models for mobile VR, Meta Quest 2 standalone)

The third change was the diversification of the platform on which the project will be built. Previous versions of the project developed only PC-based VR content as a test field. However, XR toolkits used in newer versions of virtual reconstruction can refine game graphics rendering methods such as texture quality and mesh count, making a project capable to be built for various platforms. As a result, the project was built with two platforms in mind: PC-based VR.

The fourth major change was the change in the rendering pipeline that affected the visual output of the VR environment. The LightWeight Render Pipeline (LWRP), which was used for the first project build, and the Universal Render Pipeline (URP), which was used in the 2022 version of the project, are both scalability-oriented mid- to low-resolution render pipelines for various platforms. However, URP has the advantage of applying post-processing capabilities provided by Unity without extra processes (Unity Technology, 2019). As a result, post-processing effects such as bloom, colour correction, and depth of field can be added within the virtual environment, making it easier to better control the visual appearance of the environment in the new production process using URP.

4.6.2 Assembling the 3D Models

The 3D *Choga* data was modified and then exported from Blender in two formats: FBX and OBJ. FBX is suitable for objects that are animated (dynamic), while OBJ is more suitable for static, unchangeable objects. While importing those models into the game engine, each object was divided into one of two groups according to this difference. Figure 94 shows the group of dynamic objects that the user can interact with (or that interact with the user) during the experience: objects that can be influenced by the NPC house gods, and objects related to missions. In contrast, objects that form part of the buildings and topography belong to the non-interactable object group (see Figure 95).



Figure 94. Group of interactable (dynamic) game objects (highlighted by grey wireframe)

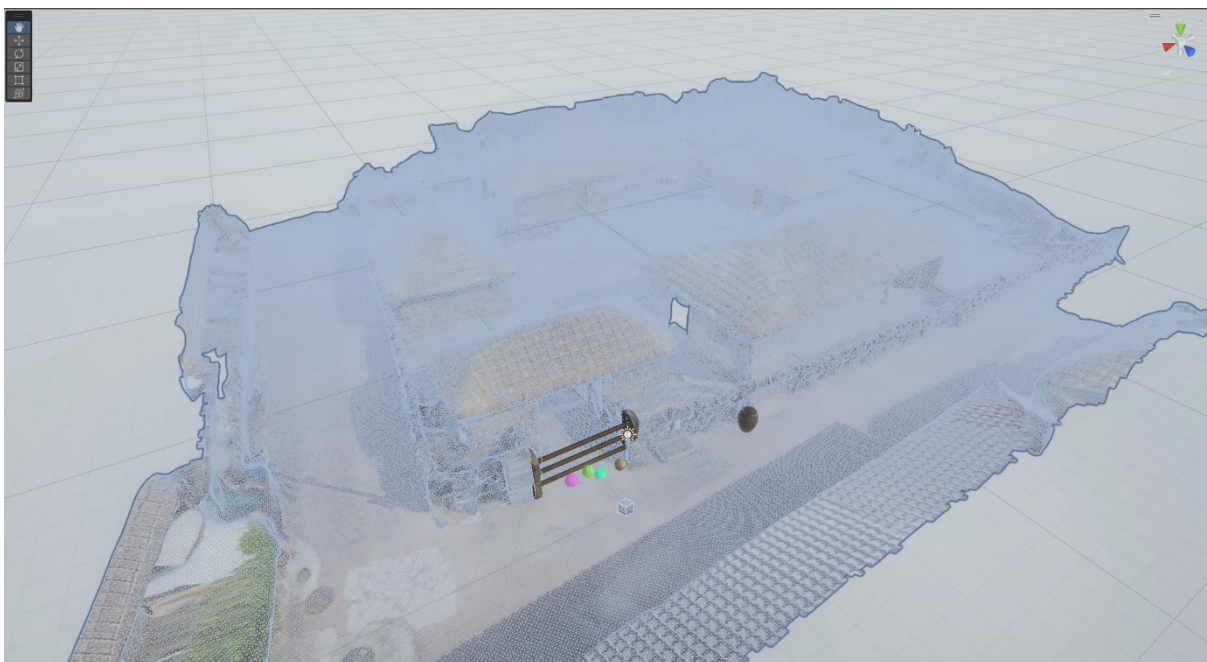


Figure 95. Group of non-interactable (static) game objects (highlighted by grey wireframe)

4.6.3 Material Shaders

In addition to the 3D models, the target platform choice also influences the choice of material shaders for objects. In Figure 96, the left shader for PC-based VR provides a diffuse map, specular map, normal map, height map, occlusion map, and environmental reflection, resulting in high visual detail, but also requiring a high-performance graphics card. In contrast, the right shader for standalone VR is limited to only providing a diffuse map on each mesh, but is suitable for lower-performance rendering hardware.

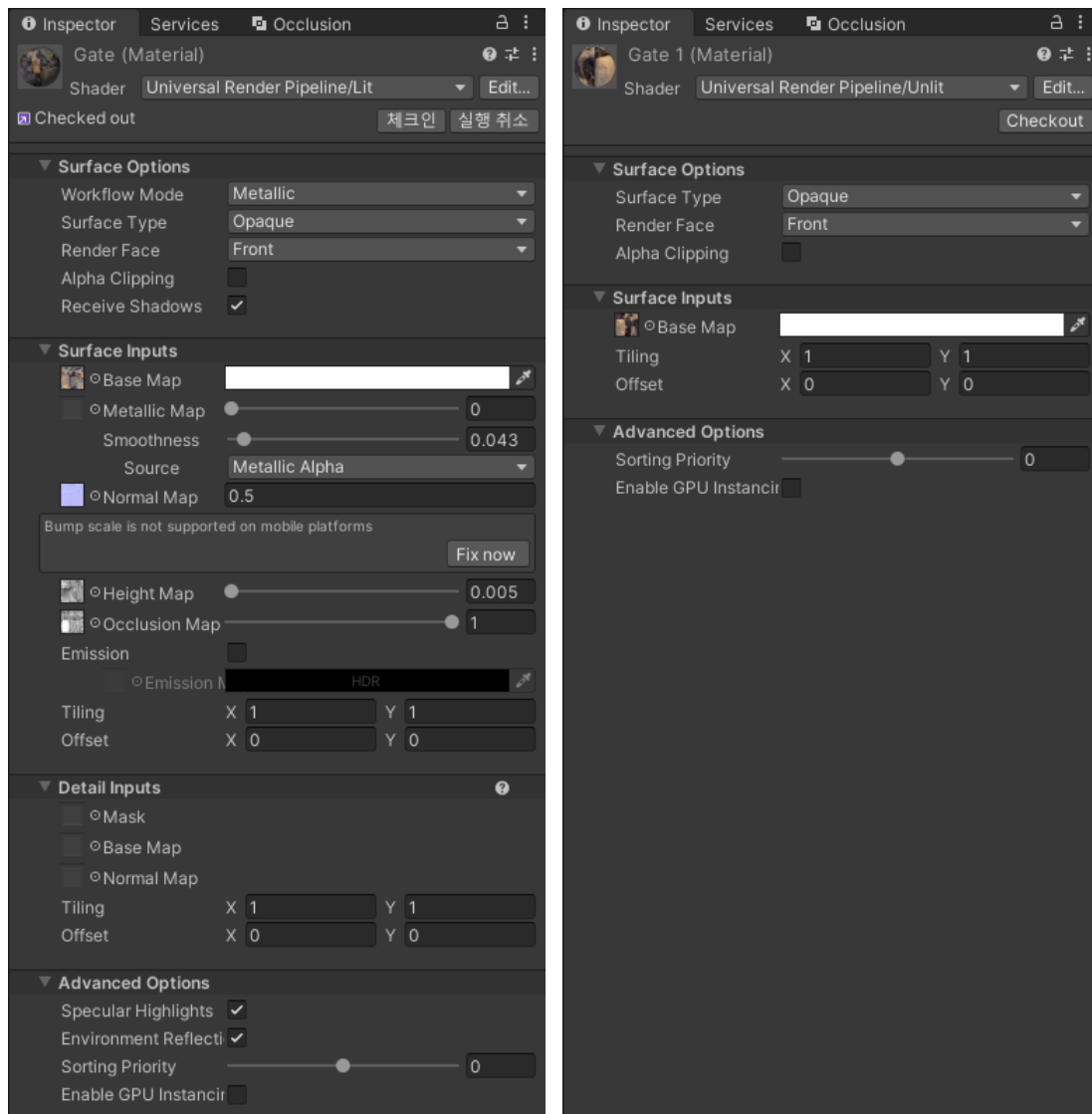


Figure 96. Different *Unity* material shaders (left: PC-based VR, right: standalone VR)

4.6.4 Comparison of PC-based and Standalone VR

This final section provides a visual comparison of the PC-based VR version and the standalone VR version of the virtual heritage application, which can also be downloaded

from <https://bit.ly/virtualchoga>. The screenshots below (Figure 97 and Figure 98) were achieved on the following hardware:

PC-based VR device:

CPU	AMD 5800X
GPU	Nvidia 3060 TI
RAM	64 GB
Graphics RAM	8 GB
OS	Windows 10

Standalone VR device:

Device	Meta Quest 2
CPU	Qualcomm Snapdragon XR2
Display	2×1832×1920 60/72/80/90/120Hz Fast-switch LCD
Storage	64 GB
RAM	6 GB
OS	Android 10

Due to the differences in computational power between those two platforms, the application for each was composed of a scene with objects that had different polygon count and material shaders (see sections above and Figure 97). Figure 98 illustrates the resulting visual differences between the two device versions. PC-based VR objects display more realistic surface representations due to the combined effects of lighting on the more detailed meshes and additional detail provided by normal maps included in shaders (top in Figure 97). In contrast, in the standalone VR version, which prioritises the device's performance, objects were simplified into lower-resolution meshes and represented only by the diffuse colour maps in their material settings (bottom in Figure 97). The result is a “flatter” look that is even more pronounced when viewed in VR.

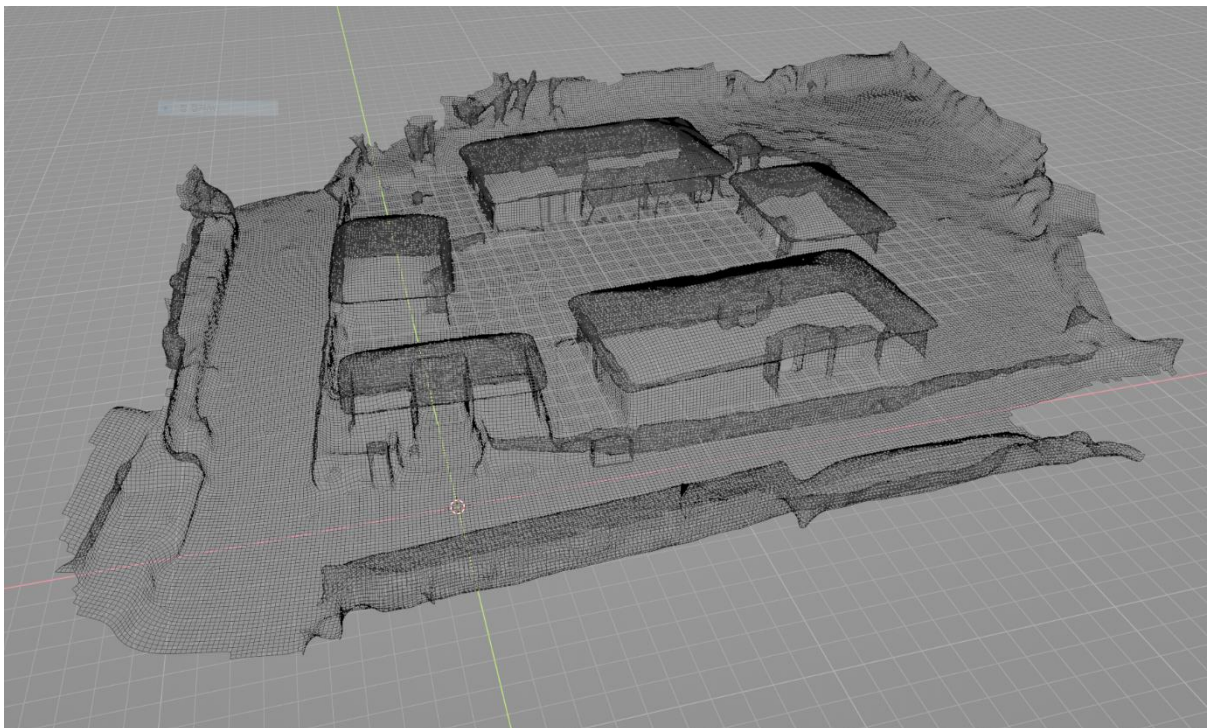
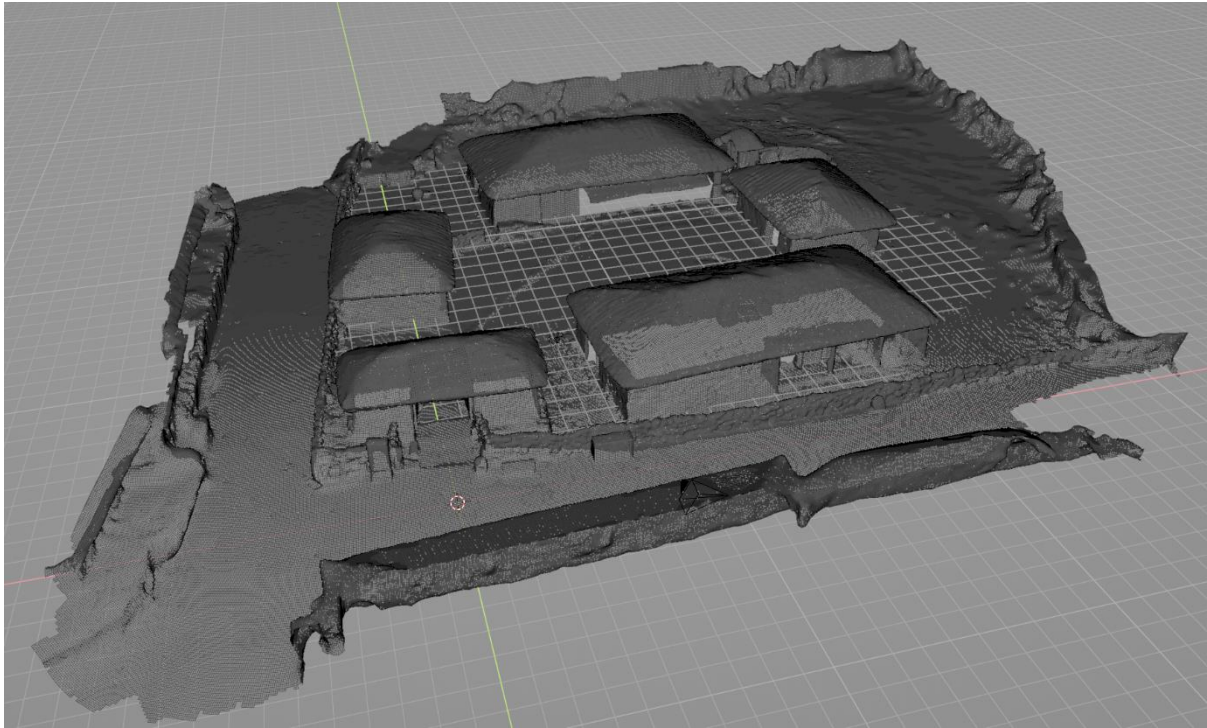


Figure 97. Comparison of the polygon count and density for the PC-based VR scene (top, 834,791 polygons) and the standalone VR scene (bottom, 134,611 polygons)



Figure 98. Comparison of the visual quality of the PC-based VR scene (top) and the standalone VR scene (bottom)

Chapter 5. Discussion and Future Work

5.1 What has been done?

In recent years, digitalisation for the preservation and education of cultural properties and cultural spaces has become more widespread. In addition, access to digitalisation technology has improved due to the simplification of various data collection equipment and applications.

With this improvement of technology, as the first approach for my study, I started to explore what enhancements are needed to improve the interest and play experience in virtual cultural heritage. In this context, a practice-based approach was run through creating a mission-based playing path related to spatial characteristics, developing a story based on a local myth from the cultural background and designing characters based on the local legend for guidance. A traditional heritage building, *Choga* in Jeju, was my target for producing VR content. I designed a modulated playing path with a playable mission like a game to create a serious game for *Choga*. Also, I selected certain household gods and developed their characters to give them a role as a Non-Playable-Characters based on local myths. In the fieldwork, scanning the traditional heritage object was done using the photogrammetry process directly after my arrival to Jeju. After data acquisition, I was confronted with a range of artistic and development issues, e.g., the inability to supply data lost during the scanning process. In addition, my research got stuck in limbo with the onset of the COVID-19 pandemic and personal health issues.

While my health improving and the global pandemic situation started to ease, in 2022, I reformulated the main task of my research to focus on a more specific practice of combining multiple scanning methods to improve its process and outputs. I tested and compared two types of 3D scanning methods, mobile LiDAR scanning and videogrammetry. I was able to travel back to the site and tried both scanning methods as a hybrid scanning approach to solve data acquisition issues that manifested during the 2019 scanning process. During the re-scanning process, I observed that the field work was more convenient by using hand-held only gear, and an increase of scan coverage by mixing the two methods. Hybrid scanning showed better data acquisition results than expected for generating 3D model components for a serious game. Mobile LiDAR scanning was used for darker environments (i.e., interior spaces), and videogrammetry was used to collect a wide range of traditional heritage site data. Even without cloud point data, the generated model from videogrammetry worked well to allow me to align each 3D scanned model in the photogrammetry software. For use within

the VR application, the collected scanned data were modified using 3D modelling and texture software to organise the mesh and texture data of each model.

While preparing for the second data acquisition, my main research question was reformulated as "can mobile phone-based LiDAR and videogrammetry scanning technology be used to supplement traditional photogrammetry scanning technology? Furthermore, can it serve as an alternative in certain environments?" The question was confirmed during the data collection, editing and polishing process. The data collection method of fusing video data and LiDAR data using mobile phones without the use of high-tech optical equipment was also able to collect more and more diverse information in a shorter time than the data collection journey in 2019. This shows that mobile phone-based LiDAR and videogrammetry scanning technology has the potential to be used not only as an auxiliary tool, but also as a central research method.

To develop the VR application, before the pandemic, I aimed to create a playground where users learn about the target cultural heritage with simple gamification resources as a serious game. To achieve this mission, I used the Steam VR input system for desktop compatibility to create in-game interactions. I sorted and manually developed reasonable interactions on the controller configuration of this input system according to designed missions from the pre-production stage, such as grabbing, holding, moving and teleporting interactions. Especially the teleportation system was designed to allow the users to change location by touching a miniature map on their wrist. In addition, household gods were created as 3D characters to act as companions while also creating interactable game objects, e.g., doors, vases and traditional totems.

After the pandemic "limbo", the focus of my research changed to mainly check the results of the second data acquisition trip, and I reduced the importance of completing the project as a serious game. Additionally, development for two different VR platforms, mobile-based (standalone) and PC-based, was considered due to a change in the VR input system support for game engines. In addition to the re-generated *Choga* site, household god models and other game objects were used to be components of the game scene. However, most developed interactions were shifted in the new input system, and some interactions were abandoned due to the changing aim of my project.

5.2 Implementation

There are many options for preserving cultural heritage and implementing a virtual reality version of them, but it is now possible for not only professionals, museums, or academics.

Yes, sophisticated scanning method for the accurate digital capture of scanning objects still come with high costs and the need for prior training. However, light tasks for individuals are becoming more accessible through the miniaturisation of devices and the advanced functionality of smartphones. It was unintentional, but my research was implemented as a hybrid workflow in the data acquisition stage.

The first workflow was detailed photogrammetry scanning for fully collecting structural data of the traditional house. The second was a mixed-scan method that was used to interpolate gaps in lost data by collecting as many different data as possible in a short period of time.

Serious photogrammetry generates high-quality data for 3D models or point cloud data in various industries, not only in the game development area. This workflow can be improved by leveraging additional data collection techniques, such as a LiDAR scanning, deep planning, pre-field testing, and high-resolution data collection devices. Scanning results showed high accuracy for reproducing the target's surface during the data acquisition phase with photogrammetry. As a game object for level design components, this high-resolution data is often used to make a tiled texture for covering the polygon space and making it appear photorealistic. In the same context, collected data was successfully used to generate texture data for the manual model that supplemented a missing part of the house scan. However, except for that part, it was pretty challenging to recreate other missing pieces that could not be referenced naturally.

Hybrid scanning, a mixture of videogrammetry and MLS, is implemented in my second workflow. Mobile LiDAR scanning, MLS, is a growing technology in many industries that typically includes advanced data collecting, such as SfM and SLAM. My approach aimed to achieve a middle-level data acquisition process suitable for the game pipeline by MLS's rapid data collecting ability. Through a smartphone application, generating 3D scanning data can be provided to every individual with simplified processing in one device. Even though MLS by itself works well enough to generate enough quality data to use in non-complex content with the game engine, the hybrid workflow that combines data from videogrammetry further improves the result by aligning and merging each output as one large dataset. This convenience can promote increasing interest in low-cost preservation of local heritage and provide this content for not only high-spec devices, e.g., desktop applications, but also for low computing power devices such as mobile devices or standalone VR HMDs.

Also, with development convenience from the built-in input systems in the game engines, the data can be provided as a serious game for many users on various platforms. This could not only be used for *Choga*, the traditional house of Jeju Island, which was my project's specific

target, but also to turn local cultural heritage or sensitive cultural properties of other countries into digital content, e.g., items of Aotearoa's/New Zealand's Māori culture as demonstrated in the showreel of the company RealityVirtual.co (REALITYVIRTUAL.CO, n.d.).

5.3 Recommendation

As mentioned in the Implementation section above, the hybrid scanning method between videogrammetry and MLS can be used in various personal and industrial applications. In the following, I will discuss the caveats and recommended uses for each technology based on my experience during the second round of 3D data collection.

As mentioned in Section 4.4.3, videogrammetry allowed me to quickly collect consecutive frames through video recording, minimising changes in the shooting environment that could affect the quality of data acquisition. However, shaky data may be collected if there is a mismatch between the frequency of frames per second of the camera and the speed of the subject's movement or movement along the camera's path. In this case, it is recommended to manually filter the shaky photos from the collected data or to install a secondary rail on the camera so that the movement speed is uniform. In addition, based on field experience, the recommended shooting subjects are buildings or equivalent large objects widely distributed on a flat surface without significant elevation differences.

MLS can be used to scan geometry in dark, isolated environments or tight spaces with a lack of light that traditional photogrammetry cannot collect without artificial light sources.

However, depending on the mobile application utilised, the collected data varies in terms of the type of file that can be extracted, the method of data generation, and the quality of the accompanying textures. This means that users can not control the quality detail and have to rely on the application developers. Therefore, selecting the right application for the collection project is necessary before collecting MLS data.

5.4 Limitations

My project's aim was changed from creating an experience in form of a serious VR game showcasing cultural heritage to improving my scanning workflow to provide advanced data acquisition for the serious game. Even though each main task is linked to a serious game and focuses on processing and optimising 3D-scanned content for use in a game engine, there is a lack of organic connectivity between the first and second phase by the changing importance of the implementation stage between pre-production and production.

I redesigned the second phase's task due to issues encountered in the fieldwork of the first phase. Specifically, data omission and data corruption was observed during the data-generating process. There is a concern that a lack of my personal expertise might have caused that issue, also likely affecting my research's solidity. Even though the second phase produced an improvement, data acquisition for specific parts, e.g., missing roof textures, indicates that there is still need for improvement for the process of complementary hybrid scanning using MLS and videogrammetry. The trajectory of my research changed to improve data acquisition between the first and the second phase.

Lastly, although I successfully combined the scanned data with the VR interaction implemented in the first phase, the development of the originally planned narrative and VR interaction remained incomplete, so there is insufficient verification for the entire application as a useful serious game.

5.5 Future Work

While the changed task of improved data acquisition from cultural heritage was achieved, the original plan for the project outcome of a finished form of a serious game was not fully implemented. This was due to scaling back the proportion of the game-pipeline workflow in this project by changing the main task to focus on data collection. Completing a high-performance game pipeline (i.e., game mission and interaction) is still a significant task to convey the interest and play experience as a serious game in the virtual world, not just the preservation of heritage, for the future improvement of this project. After completing extra development for this project as a serious game, in the short-term vision, it can be designed to compare the efficiency of cultural heritage education between a virtual tour with non-gamification content and a virtual journey with gamification and guides as NPC.

As a long-term vision for future work, there is a desire to gradually expand and create an entire village, starting with the data of *Choga* in the project. During the second phase, simplified equipment and mobile standalone data generation processes significantly reduced the difficulty of digitisation for the target heritage. In addition to this simplification of data collection, it can be implemented as an open playing field that can execute the combination of a variety of collected data as a multi-platform. In this creative space, digital preservation of cultural heritage can be completed as a public project involving users, not just experts. To elaborate, judging from the trend of ever increasing convenience and usability of devices, users can assume the role of a traveller using the virtual world created through scanning results and the role of a producer who provides information to the virtual world. This role of a data contributor to virtual heritage will promote more interest in cultural heritages that are

being forgotten around us and ease of voluntarily collecting various data by users as gamification content.

Chapter 6. Conclusion

More and more people learn about cultural heritage through various interactions such as accessing virtual museums in their country or abroad through various devices and platforms. I think the continuing development of technology and the wide-ranging international or regional restrictions caused by the COVID-19 lockdowns contributed to this trend.

My project went through a significant change as well, shifting the project's primary mission, data acquisition process, tools and programmes, like a cicada's ecdysis in summer.

However, during the journey, I did not give up my belief that my project could successfully convey my childhood feelings and wonderings from grandma's house to the audience.

To realise this vision, I created a virtual cultural heritage that underwent a transformation in two stages, from narrative-centered content design to process improvement centered on hybrid 3D data acquisition, resulting in a prototype application executable on two different types of VR devices. The reproduction of cultural heritage through hybrid scanning allowed me to explore all the possibilities and provided me with confidence that further developments, such as improved convenience in data collection and simplification of equipment, can be achieved through future research. I hope that this project will not only serve as an example for my own research achievements but also for industry professionals and many others to easily access and start experiencing through easy accessibility.

By utilising hybrid 3D data acquisition, I hope that everyone can preserve their own precious memories of places and meaningful experiences, just like the dream of being able to visit my grandmother's old house again.

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Appendix

Appendix 1. Level Design

Playing Experience for the User

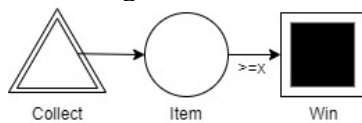
- To provide improved immersion through the natural narrative
- Spontaneous accepting the role (or persona) during play.
- Self-competence. Get confirmation from each god to complete the mission (like a badge in Pokemon).

Quest Locations

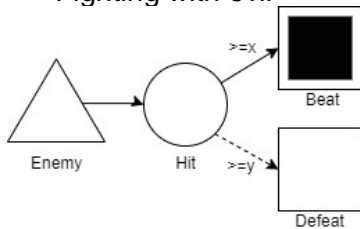
- Town
- Gate
- Inner yard
- Inner house – kitchen, storage, living room and bedroom
- Outer yard

Quest Mechanics

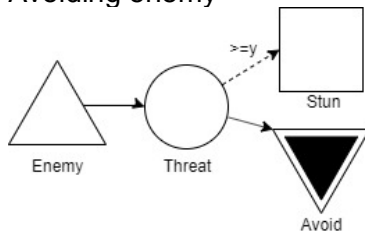
- Collecting item



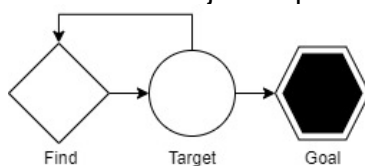
- Fighting with evil



- Avoiding enemy



- Interact with object or place



Aspect Based on Cultural Myth (Background)

- The distance between the kitchen and the toilet needs to be as far as possible. People in Jeju believed that bringing the object from the kitchen to the toilet or vice versa could cause accidents or injury.

Appendix 2. God Character Design

Moon-Jeon Shin

- Personality: Wise, to the individual: friendly, to god: negotiator
- The same legend with Jo-Wang Shin and Chuck Shin
- Jo-Wang Shin: mother, Chuck Shin: feud (murdered mother)
- Sung-Ju Shin: protect land and house from evil (disaster, disease and gate crasher)
- Needed appearance: the symbol of the gate, colour: white (for representing wisdom)

Jo-Wang Shin

- Personality: Charity, to the individual: friendly, to god: supporter
- The same legend with Moon-Jeon Shin and Chuck Shin
- Moon-Jeon shin: son, Chuck Shin: feud (killed her)
- No similarity
- Needed appearance: the symbol of the fire, colour: red or orange

Sung-Ju Shin

- Personality: Bold and strict, to the individual: reticent, to god: supporter
- No same god (only based on Sung-Ju-pul-e)
- No personal relationship.
- Moon-Jeon Shin: protect land and house from the evil (disaster, disease and gate crasher)
- Needed appearance: old, the symbol of the guardian, colour: blue (for representing the guardian)

Ahn-Chil-Sung

- Personality: Sharp and negative, to the individual: introverted, to god: not too much connection
- The same legend with Bat-Chil-Sung
- Bat-Chil-Sung: daughter
- Bat-Chil-Sung: save the wealth for family
- Needed appearance: the symbol of the snake, colour: gold (for representing wealth)

Bat-Chil-Sung

- Personality: positive, to the individual: extroverted, to god: over-active
- The same legend with Ahn-Chil-Sung
- Ahn-Chil-Sung: mother
- Ahn-Chil-Sung: save the wealth for family
- Needed appearance: the symbol of the snake, colour: gold (for representing wealth)

Chuck Shin

- Personality: negative, to the individual: avoiding, to god: no contact with others
- The same legend with Moon-Jeon Shin and Jo-Wang Shin
- Is being punished
- Jo-Wang Shin: victim, Moon-Jeon Shin: feud (murdered his mother)
- No similarity
- Needed appearance: melted surface, colour: green (for representing danger)

Appendix 3. List of Acquisition Gear

Category	Type	Name	Condition	Borrowing due	Price (rental) / amount	Image	Priority
Filming Equipment	Main camera	Sony A7SII	Borrowing (reserved)	12-9 to 12-12 (4 days)	45 NZD (per day) /1		1
	Lens	16-35mm 4/22f	Borrowing (reserved)	12-9 to 12-12 (4 days)	15 NZD (per day) /1		1
	Lens	24-70mm 4/22f	Borrowing (reserved)	12-9 to 12-12 (4 days)	15 NZD (per day) /1		1
	Sub-camera	Sony A57	Owned	-			1
	Lens	18-55mm 3.8-5.6f	Owned	-			1
Lighting Equipment	Light	Led-Light	Borrowing (reserved)	12-9 to 12-12 (4 days)	58 NZD (per day) /1		2
	Light	Sony HVL-LE1	Borrowing (reserved)	12-9 to 12-12 (4 days)	45 NZD (per day) /1		1
	Screen	Silk-screen	Borrowing (reserved)	12-9 to 12-12 (4 days)	3 NZD (per day) /1		2
	Screen	Light tent	Borrowing (from AUT)	11-25 to 12-26 (31 days)	0/1		1
Attachment & stand	Stand	Tripod 75mm	Borrowing (reserved)	12-10 to 12-13 (4 days)	7 NZD (per day) /1		1
	Polarised filter	Hoya (55,67,72mm)	Have to buy	-	130 NZD /3		1
	Electricity	Power cable	Borrowing (reserved)	12-10 to 12-13 (4 days)	3 NZD (per day) /1		3
Implementation equipment	Laptop-rendering	Gigabyte	Borrowing (from AUT)	11-25 to 12-26 (31 days)	0/1		1

	Laptop Sub	My own	Owned	T -	0/1		1
	Data storage	WD 1TB HDD	Borrowing (from AUT)	11-25 to 12-26 (31 days)	0/1		1
	Data storage	Sdxc 64GB	Owned		0/2		1

Further Considerations:

Changing the main camera (borrowing Canon 700D from Jeffrey).

Add a gimbal diffuser and light to the list.

Ring light is difficult to find. Consider buying Godox ring light, but it may need time for shipping to Korea.

Borrowing from the Association of Media and Culture in Jeju:

<http://jejuafc.or.kr/service/equipmentList.sky?code=equipmen&groupCode=JIWON&checkDate=&equipTypeCode=ET0001>

Appendix 4. Research Visit Request

Research Visit Request			
Name	Li Goan Ko	Affiliation/Degree	Auckland University of Technology (New Zealand) / Master of Creative Technologies
Contact	... redacted ...		
Purpose of visiting			
To capture research materials for a paper.			
Research Topic			
Fusion of VR (Virtual Reality) technology and storytelling from myths and legends to guide and educate visitors in traditional Jeju houses, aiming to enhance their immersion and interest. (For both locals and foreigners)			
Specific Research Objectives:			
<ol style="list-style-type: none"> 1. Create a virtual environment through 3D modelling of traditional Jeju houses, their interior and exterior features, and traditional lighting. 2. Use the gods from the myths and legends associated with Jeju houses to guide visitors through missions and requests that naturally facilitate understanding of the structures. 3. Provide a realistic experience by applying sound, wind, and lighting effects. 			
Capture Method			
<ol style="list-style-type: none"> 1. Collect 3D data through photogrammetry by taking multi-angle photos of each building and traditional feature. Approximately 1400 photos will be required, including 800 of the buildings and 600 of the surrounding environment. 2. Collect data through 3D scanning equipment of the buildings. Eight scans will be expected, four for external and four for internal. 			
Expected Visit Period			
Approximately three days between December 9th and December 13th, 2019			
Inquiries			
<ol style="list-style-type: none"> 1. Request for floor plans of traditional Jeju houses. This will help with the creation of educational content (user flow, interactive programming, content planning) before photo shoots. It will also allow for the pre-selection of suitable sites since the interior structure of traditional houses varies by household. 2. Request for the insertion of CI (Corporate Identity) into the content to be completed before the content is offered for Jeju Folk Village. 			
Reference			
Example project of a virtual reality content of the Japanese Okuno-In Tomb https://blogs.unity3d.com/kr/2019/08/01/the-power-of-photogrammetry-simulating-the-real-world-in-vr/			